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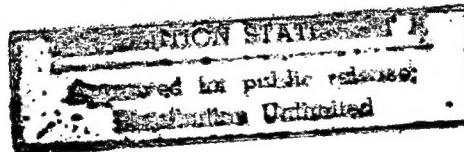
JPRS-CST-86-009

13 March 1986

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China Report

SCIENCE AND TECHNOLOGY



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13 March 1986

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SCIENCE AND TECHNOLOGY

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NATIONAL DEVELOPMENTS

'SPARK PLAN' PROJECTS OFF TO QUICK START

Tianjin JISHU SHICHANG BAO in Chinese 17 Dec 85 p 1

[Article by Zhu Qingfang [2612 1987 5364]: "'Spark Plan' Projects Satisfy Urgent Rural Need for Scientific Know-how"]

[Text] The implementation of the "Spark Plan," approved by the State Council, is in full swing at present. As of late November, 40 projects involving state investments have been planned. Provinces, autonomous regions and municipalities directly administered by the central government are also working out their own "Spark Plans."

Reports suggest that "Spark Plan" projects have been able to get off the ground so quickly because, first, they are oriented toward rural and township enterprises and villages. They adapt to the technical standard of these enterprises and tackle the right kind of technology. The "Spark Plan" will be the engine which powers the technical modernization of rural, township, small and medium-sized enterprises and helps the vitalization of local economies. Second, "Spark Plan" projects focus on aquaculture, the fast breeding of poultry and waterfowl, the production of livestock products derived from herbivores, the processing and use of agricultural products, rural construction and the development of related products. They make full use of all kinds of local resources and do not compete with large enterprises for energy and raw materials. Third, "Spark Plan" projects are selected with consideration for an array of factors like market, raw materials, technological standard and pollution prevention. Projects also come with measures to manage investment and the import of technology, providing the ideal conditions for their implementation.

The proposal and realization of the "Spark Plan" have caught the attention and interest of leading comrades on the CPC Central Committee. Recently Vice Premier Wan Li said, "Villages and townships have a crying need for science and technology. Today it is the countryside which shows the greatest enthusiasm for scientific and technical knowledge. People there urgently need to improve labor productivity, produce more products, shake off poverty and become well off. We must channel science and technology toward the villages through reform. That way, not only will rural and township enterprises thrive, but agriculture will also be able to do much better." He also said, "The 'Spark Plan' is well conceived, something the masses of peasants badly need. It is a vast world out there where much can be accomplished. You must work hard and hang in there for a couple of years. Success is a foregone conclusion."

NATIONAL DEVELOPMENTS

'SPARK PLAN' DELIVERS SCIENCE, TECHNOLOGY TO COUNTRYSIDE

Tianjin JISHU SHICHANG BAO in Chinese 17 Dec 85 p 1

[Article by Cheng Yinsheng [2052 6892 3932]: "'Spark Plan' Projects Will Set the Countryside Ablaze With Technology"]

[Text] The "Spark Plan" has attracted the attention of people from all walks of life because it aims at delivering science and technology to the vast countryside and myriad townships and contributes to the development of rural and township enterprises and the vitalization of local economies. It completely conforms to the trend of scientific and technical reform and satisfies the demands which the goals of national economic development make on scientific and technical work during the "Seventh 5-Year plan" period.

Since the 3d Plenary Session of the 11th CPC Central Committee, the situation in the countryside has been getting better and better. But because of our weak agricultural base, peasants in some areas still do not have enough to eat or wear. The masses of peasants fervently hope to increase labor productivity and create more wealth so as to eradicate poverty. Following the development of rural commodity production in recent years, peasants have grown keenly aware of the lack of expertise, technology and qualified personnel in the countryside. They became convinced that the vitalization of the rural economy depends on first, policy, and second, science and technology. The "Spark Plan" is exactly an exploration and experiment in the combination of policy, on the one hand, and science and technology, on the other. Moreover, it coincides with the urgent desire of countless peasants for science and technology. The implementation of this plan will be the spark setting the countryside ablaze and deliver to rural and township enterprises the key to the door of development.

Setting the Countryside Ablaze Requires Igniters

To increase rural labor productivity by an appreciable extent and kindle the fire of modernization in the vast countryside, a crucial step is to train a group of grassroots cadres and high school graduates. As things now stand, our grassroots cadres lack training in modern social management and science and technology, while our numerous high school graduates, though bursting with youthful vitality, have no professional, scientific or technical training. To set the countryside ablaze, we need people to fan the fire. If we give

grassroots and high school graduates just a modicum of training and equip them with a skill or two, they can certainly make themselves useful in the magnificent undertaking of rural modernization. Besides attracting over 100 qualified people to the county, the Science and Technology Commission of Hengdong County, Hunan, organized 30 technical training courses in the second half of this year and trained more than 3,000 people, which enabled the county's rural and township enterprises to increase output value by 1 million yuan. Then there are localities which make full use of all manner of professional schools, institutions of higher education and research institutes to turn out qualified technical personnel for rural and township enterprises.

Development Projects Chosen With An Eye To Local Circumstances

The point of departure for the "Spark Plan" is the coordination of the economic, social and environmental results of rural development. The purpose is to base the technical advancement of rural enterprises squarely on agricultural development. A total of 14 technical fields have been selected for priority development this year and next. Conditions in China's countryside vary considerably. Each locality has its own personality and special circumstances, so science and technology in the countryside must be individualized. In selecting development projects, we must carefully consider the local conditions and possibilities. Successful projects in such fields as breeding, processing of agricultural products, mountain area development and building materials can be expected to have a positive effect on the locality's economic take-off.

Hard Work Needed To Develop Own Technical Capability

It is in technology that qualified personnel and projects come together. The significance of the "Spark Plan" lies in the encouragement it gives to villages and townships through demonstration to develop their own technical prowess from practice in order to facilitate their further growth. Analyzing the overall situation, we see that villages and townships do take the import of technology from other parts of the country seriously, use the import to propel their own technical advancement and work hard to develop their own technical capability. Right now there are over 200 rural and township enterprises in Shanghai which are shifting from labor-intensive operations to technology-intensive ones. Such technologies as duct forming equipment, clothing buttonhole lockstitcher, and plastics molding press have all been channelled toward rural and township enterprises. About a dozen agricultural technologies, including the cultivation of quick-ripening oranges and tangerines and fish-breeding in paddy fields have breathed life into and invigorated the villages in Ling County, Hunan.

Transfer Technology To The Countryside Through the Technical Market

At present, technical markets are thriving everywhere. The full use of such markets to facilitate the transfer of technology to the villages and townships is an pioneering journey on which various localities have embarked, charting their own road map. The Hebei Provincial Science and Technology Commission has demanded that municipal and county technical markets provide rural and township enterprises with information through various channels and in

different ways; assist villages import technology and recruit qualified personnel; and offer them a full range of technical services. To promote the development of rural and township enterprises, the Science and Technology Commission of Foshan County, Guangdong, gives priority to the implementation of projects with a short turnover time which require little capital and produce quick results. By acting as a go-between, it has opened the door through which technology can enter the countryside.

It is a foregone conclusion that through the concerted efforts of people in all trades and at all levels, a single spark can set the entire countryside ablaze.

12581
CSO: 4008/2048

NATIONAL DEVELOPMENTS

TECHNOLOGY IMPORTS BEGIN TO PAY OFF

Beijing RENMIN RIBAO in Chinese 14 Jan 86 p 2

[Text] According to comrades from localities and departments which took part in the national economic work conference, the technology we imported in the "Sixth 5-Year Plan" has begun to pay off.

During those 5 years, the state, localities and departments imported from abroad about 14,000 items of advanced technology, of which the bulk were used to modernize small and medium-sized enterprises. Both practical and modern, many of them were bought, installed and went into operation the same year.

The experience of various localities proves that after delivery and put into production, these technologies have begun to pay off in the following four ways:

1. a good return on investment. They are earning and saving foreign exchange for the state. According to an analysis of imports which have been put into service in Beijing, Shanghai and Tianjin, output value rises by 2.5 yuan to 2.8 yuan and profit tax by 0.5 yuan to 0.8 yuan for every yuan invested. The entire investment can be recouped in 2 or 3 years.

2. speeding up product renewal and succession, filling a technical vacuum in the national economy and promoting the development of new materials. In recent years, the machinery industry has imported over 500 pieces of technology, accelerated product renewal and succession, filled some technical gaps in the nation and pushed some 5,000 products to the level of the late 1970's and early 80's.

3. promoting absorption and the substitution of foreign products with domestic ones. From test manufacturing single pieces of machinery, we are now beginning to make whole plants.

4. Technology import has furnished enterprises with qualified personnel, technology, equipment and managerial experience and speeded up their technical modernization and reorganization.

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CSO: 4008/2048

NATIONAL DEVELOPMENTS

REFORM OF SCIENCE, TECHNOLOGY PLANNING MANAGEMENT SYSTEM

Jinan DAZHONG RIBAO in Chinese 6 Nov 85 p 4

[Article by Zhang Junhua [1728 0193 5478]: "Major Issues in Reforming the Science and Technology Planning Management System"]

[Text] Reforming the science and technology planning management system is an important part of implementing the CPC Central Committee's resolution on restructuring the science and technology system. In this connection, the following issues merit our special attention:

(1) Science and technology development planning and national economic planning must proceed in tandem. Generally speaking, science and technology can be transformed into material economic capability through popularization and application. The development of such a capability, in turn, is bound to influence science and technology by posing it with new research topics which, ultimately, will lead to further economic growth. For this reason, science and technology planning and economic development planning should be integrated and considered in a broad context, instead of being confined to watertight compartments. Specifically we should set up a guiding agency for comprehensive planning whose responsibility will be to draw up a general planning outline. The various departments in charge will then formulate plans for their own subordinate bodies under the guidance of the general planning outline. Finally the departments should come together to harmonize and finalize their plans through analyses, justifications and revisions.

(2) The coexistence of guidance planning and command planning in science and technology. Like the socialist economic planning system, the science and technology planning system should embody both unity and flexibility and manifest itself as guidance planning as well as command planning. Years of practice shows that the exclusive reliance on command planning led to over-centralization, the result of which is that the state became overburdened while many counties and municipalities had no projects to work on. Also, it led to such negative tendencies as level after level ignoring what was key technology in the localities and emphasizing what they called "advanced, feasible and rational," resulting in a single-minded pursuit of "high-grade, precision and advanced products." In formulating their science and technology plans, therefore, all levels should combine projects in the command plan, which are vital and have overall significance, with projects in the guidance plan, which benefit local development as well having broad significance.

(3) Matching science and technology investments by the state with science and technology investments by localities. One way to influence science and technology planning is through investment. Traditionally, local investments in science and technology bore no relationship to national economic growth or to local budgetary conditions. The state was the only funding agency for science and technology and direct appropriation the only funding method. Investments were simply spent and not required to be paid back. All this put a ceiling on the number of projects we could undertake and made for inferior science research conditions. As a result, science and technology development was stunted. The present effort to alter this situation revolves around the reform of the funding system. Even as we adopt a system of classified management for science and technology funds, we must also proceed to match state investments with local investments, establishment local technology development funds and increase local contributions using a variety of channels, approaches and methods so that state and local investments will come to depend on, relate to and interact with each other. Localities in the Huimin area, for instance, set aside a portion of their revenues to help counties and municipalities establish technology development funds. Regulations were also drawn up stipulating that counties and municipalities will receive appropriations only after dipping into their own science and technology development funds. The result is that overall science and technology appropriations in that area rose 8.7-fold over a year ago.

(4) Simultaneous management of science and technology funds by science departments and banks. It works this way. The science department is responsible for the overall supervision of a particular project while the bank oversees and manages the way the funds are spent throughout the project. This system of dual supervision goes into effect after the three parties--the science department, the unit which undertakes to do the project, and the bank--have signed an agreement. Its advantages are that economic mechanisms can be used to tighten financial management discipline and investments are used to the full. It also facilitates the recoupment of capital.

(5) The compensatory contract system and the project contracting system can proceed side by side. Under the former system, after determining whether the costs of a project are to be repaid in part or in full, the parties concerned also spell out clearly the contents of the project, its goals, the responsibility of each party involved, reasonable rewards and penalties, and the date by which the funds should be repaid. Under the latter system, only the responsibilities, rights and interests of scientific research personnel are clearly specified. These two systems exert pressure on the unit which undertakes to do a project and the project group, but they also inject into them a measure of vitality.

(6) Science and technology planning should be better coordinated. At present there is no coordination between functional departments at various levels. Say a department wants to increase science and technology appropriations, a request, however, which may not end up in the budget. Another department may want subordinate agencies at the lower level to increase science and technology investments only to be thwarted by the finance department at the same level saying that the lower agencies have not got their accounts right.

This lack of coordination is due to a multitude of factors. Therefore, we should work out measures in a coordinated way so that the science and technology policies of the localities can take into account local conditions and remain flexible without violating the policies of the higher authorities.

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CSO: 4008/2049

NATIONAL DEVELOPMENTS

PLANS FOR REFORM OF ALLOCATION SYSTEM DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENTIOLOGY AND MANAGEMENT OF S&T]
in Chinese No 10, 12 Oct 85 pp 19-21

[Article by Sang Yiye [2718 0001 0673], Dalian Municipal Science Education Committee: "A Discussion On the Restructuring of the Allocation System"]

[Text] Restructuring the science and technology funds allocation system is a key link in the restructuring of the science and technology system. Beginning last year, more than half the industrial development and applications research organizations in the city of Dalian undertook an elimination of operating expenses and implementation of a compensated contract system. By the beginning of 1987, operating expenses for this kind of research organization will be completely eliminated throughout the city. But elimination of the operating expenses for research units is not the extent of reforms of the allocation system. Having changed the old allocation methods, how are we to set up a new allocation system? On top of putting money into science and technology funds, how are we to change the decision making procedures that are the wills of senior officials and of departments and establish scientific decision making procedures? If we eliminate operating expenses based research organizations, how will there be income and how will they develop their services? In sum, how will we establish a set of operational regulations for science and technology that are even more closely integrated with economic construction? In the reform of the allocation system, these are problems that must be earnestly resolved from the point of actual work to that of ideological concepts.

There have generally been two ways to obtain scientific research funds for development and applications research organizations. One is operating expenses provided by the state, which is also called per capita fees; the other is from the three types of scientific and technical expenses allocated by the state, which includes various levels of government, and which is also called project expenses. Research units report their plans to superiors, list the projects, and when they have been arranged in order, the higher authorities then allocate funds. This kind of allocation for scientific and technical funding is called by some people "eating the public grain."

Where is the abuse in "eating the public grain?" One, because when units engaged in development and applications research "eat the public grain," they

are ensured of a steady income despite conditions, and they lack an internal sense of urgency and of crisis for problems that exist in development, and their sense of competition is weak. They only have enthusiasm for dealing with funding units, have enthusiasm only for higher authorities, and lack any pressure to cater to economic construction. Therefore, if economic results are not respected in research organizations, and they do not pay close attention to technical matters in need of urgent solution that appear in production and actual practice, then there is a serious tendency to favor papers and high-precision technology. Two, the field of vision for science and technology management departments is not wide, and they can in general only select the objects of funding from among units applying for projects; this means that units are always competing on the basis of the enthusiasm that comes from competing for projects, and they neglect the needs of economic construction for those projects and do not take seriously developing competition along the lines of research capacity. The result of all this is that the stronger projects needed in economic construction cannot necessarily be chosen, nor will those units with greater research capacity necessarily be given an opportunity; scientific research projects are fragmented and dispersed, and the focal points are not prominent. Three, because state financial abilities are limited, investment in scientific and technical service cannot satisfy the needs of science and technology research. Since research organizations are used to eating from the "public grain," they cannot eat less, so many research organizations and scientists and technicians that have had little or no tasking for quite some time have no enthusiasm nor pressure for finding tasking within economic construction; because of the limitations of departments with talent, those scientists and technicians who have no tasking cannot take up other work. This has given rise to a serious waste of technology, knowledge, and talent. Four, because research units have "eaten the public grain," the rights to scientific and technical achievements are transferred without compensation, and scientific and technical funds are used without compensation, which has for a long time been an important factor in the inability to commercialize scientific and technical achievements.

Therefore, the science and technology funds allocation methods that are currently in effect in a fundamental sense do not suit China's commodity economy. Restructuring of the science and technology system ought to begin first of all with a reform of the funds allocation system, cutting off the channel of "public grain," eliminating operating expenses for development and applications organizations, and changing the funds allocation methods by which research organizations report to higher authorities, listing projects, and seeking scientific and technical funding. It should also change the current planning and management system, should impel research organizations to cater to society, to cater to the realities of economic construction, to cater to the technology markets, to look everywhere for research topics, for funding, and for compensated transfer of the rights to technical achievements, all of which to strengthen gradually their own capacity for existence and development.

With this kind of outlook, development and applications research organizations will have eliminated operating expenses, and when management departments are arranging science and technology projects they should take this kind of research organization into consideration, for otherwise these units will find

it difficult to survive. This is a consideration that should not be. There should be at least two ways of understanding the restructuring of the allocation system. As far as the research organizations are concerned, that will mean the elimination of research organization operating expenses and changing the way projects are reported and funds requested. The premise of working in this way is that we must acknowledge that technical achievements are commodities and that technology development and applications research units are the producers and operators of technical commodities. We must make it clear that their existence ought to be determined by the degree of commercialization they provide for society, and that they ought not to depend upon state allocation of operating expenses, nor should they rely on projects handed down by higher authorities for their continued existence. As far as funds allocation units or management departments are concerned, reforming the ways of allocating funds means that things should be carried out according to the rules of a commodity economy, using economic levers, and keeping to the principles of coordinated development of science and technology, the economy, and society in order to arrange how science and technology funding is to be put into operation. We should not link the circulation of science and technology funding to the existence of research units, for these are two different things and should not be discussed together. But in the present funds allocation system, these sorts of discussions are common. After certain operating expenses for research organizations had been eliminated, some organizations still pinned their hopes for subsistence on whether or not the higher authorities passed down scientific research projects for their particular unit or on how many they could hand down. What we have often criticized as "sympathetic projects" or "leading cadre projects" are reflections of this sort of problem. Therefore, we cannot consider that reform of the funds allocation system is just a matter for research organizations, because it is at the same time a reform of government organization and science and technology management systems.

How are we going to manage and use operating expenses and science and technology funding from the altered allocation channels? This is a problem posed to the government management departments by the restructuring of the allocation system. A scientific method would be to use this money together with money that can be gathered through other channels to establish a science and technology development fund, and to set up a fund committee composed of the departments of science and technology, economics, planning, and finance to manage the fund. The fund would primarily be used for key science and technology projects as presented in planning, for development projects, and for absorption and assimilation projects for imported technology. These projects will make use of the methods of public bidding opened to society at large, evaluation by specialists in the field, examination and approval by the fund committee, and preferential support. As responsibility projects handled through technical and economic contracts, whoever takes the responsibility will be supported. Whether it is a research organization or a higher level institution, or whether it is an enterprise. Aside from a small amount of risk capital for these projects, use of other project funds should be maintained on the compensation principle.

Benefits of the fund committee to manage and use science and technology funds as organized by the combined departments are: 1. it can consider and

determine how to place science and technology funds from the macroscopic view of science and technology, economics, and society in coordinated development, so these things are not solely from the departments of science and technology. Therefore, in the decision making process this will change the situation where science and technology is divorced from economics, and allow it to become more scientific and reasonable. 2. It will break through the separation present in the current system due to each faction acting independently. An important factor in the separation between science and technology and economics in the past was that each department had its own planning. The department of foreign trade had a technology import plan, the economics department had a technology renewal plan, and the science and technology department had a plan for science and technology key developments, all of which were science and technology, but each was doing things its own way and there was little contact between them. This kind of system caused each department to proceed in a partial manner and lacked an overall view. To change this situation and make an impression from within this bound-up system would be very difficult. Therefore, setting up a fund committee where the combined departments participate in managing science and technology funds will be like waving a knife at the present system itself, and is a significant action and attempt. As for the management of technology importing and technology transformation funds, although each has its characteristics, as far as changing the decision making process and reforming the management system is concerned, the logic is the same. 3. Because the funds are open for bidding by the public, this enables research units, higher institutions, and enterprises to compete from the same starting line, and research units can then make efforts at competitiveness in technical research and development.

After allocation methods for science and technology funds have been changed, research organizations will on the one hand continue to strengthen the competitive capacity of technology research and development and strive to take on more of the bidding projects from higher authorities; on the other hand, research organizations will expand their vision, and seek projects in society, from enterprises, and in technology markets to find funds. Because of this, research organizations will restructure their internal management system, quicken the operating rhythm of each function, and provide for society more and more technical knowledge and products that are attractive and reasonably priced. At the same time, they will constantly increase the reserves of technical knowledge of the research organizations themselves, improve the levels of the work of scientists and technicians, maintain the "stamina" of scientific research and technical development, and in a planned way develop leading research. This is to say that after we have changed the allocation system, research units must have a commodity outlook and a view toward the marketplace. Research units will arouse an scientific and technical capacity that is greater than before to cater to enterprises and to the technology markets; a considerable number of scientists and technicians will leave the little heavens of the laboratory and extend their vision and energy toward economic construction.

Methods by which to restructure the allocation system will set up a new set of operating regulations for science and technology. This new system will be a working system having an organic structure and functions, as well as relations among them, and it will be complex. Therefore, restructuring the allocation

system will not only change the allocation methods themselves, but the other "structures and their functions" that are related to it will carry out a corresponding reform.

First of all, we will vigorously open up the technology markets, which meets the preconditions of development of a socialist commodity market and of restructuring the allocation system. The technology marketplaces are channels of technical knowledge and commodities, and are the environment of a commodity economy. Opening up the technology marketplaces, we must first acknowledge that technology is a commodity and that it will create an environment that breaks up the "public grain" by which research units have obtained their income, existence, and development, and will create an environment by which research units can allow their technical achievements to reach their value in a commodity economy. We say "one side is building up the wall as the other is breaking free," by which we mean that one part wants to cut off the means of escape where the research units eat from the state bowl and where scientists and technicians eat from the unit's bowl; another wants to create an environment that allows research units to be able to exist and develop. Basing oneself upon this sort of environment will fulfill the chances for life; to depart from these surroundings will endanger life and limb. This environment is the technology marketplace. Compete, subsist, and develop in the technology marketplace. If something cannot fit within this environment, it will die out.

Then, we will extend the autonomy of the research units. Technology development and applications research units that have lost their "public grain" are producers and operators of technical knowledge and commodities, and therefore must eliminate all former bonds between the system and the research units. An example is where we will separate government from research, will permit research units to adjust their research directions based on their own strengths, will break through the piecemeal and fragmented restraints and the separation between departments, professions, and regions, cater to society, and form broad based relations with enterprises; we will permit research institutes to implement an institute director responsibility system, give decision making authority and command to the institute director regarding research, administration, and operations throughout the institute; we will allow research units to be not restricted by established authority, to select the best for employment and to advertise for needed personnel; we will permit scientists and technicians from research units to organize and form technology service organizations of all sorts that cater to society; we will permit research units to evaluate their internal technical positions; and we will allow the net income of research units to be retained by them, etc. In summary, we will treat research units from the view of a socialist commodity economy, and will use economic levers to manage research units. Leading organizations ought to be "hand maidens" and not become again a "sea of laws," nor treat research units as adjuncts to departments, nor use the method of administrative orders to manage the research units.

We will also formulate corresponding policies to support and impel research units in subsisting and developing in the actual practice of catering to economic construction. Research units are still infants in the marketplaces of a socialist commodity economy. Management departments will work out some

corresponding policies to allow research units that have long relied for their subsistence on eating from the "public grain" to be able to have a suitable and ready program after "weaning from the grain." For example, in the steps to eliminate or reduce operating expenses we should treat research units according to their particular situations; within a certain period, to take out a portion of the eliminated or reduced operating expenses and return it to the research units through loans; in distributing income, as long as the research unit has begun to eliminate operating expenses and begun to turn toward economic construction, there should be an appropriate relaxation when it comes to distributing the technical income they have obtained, etc.

Changing the allocation system for science and technology funds will be a deep felt revolution for the science and technology system. It will not only require changing all aspects of the current situation, but will also require a thorough change in people's thinking and ideas. The present science and technology system has been formed gradually over decades, and to change an old system we must first request that the leaders, managers, and scientists and technicians from every level and department change their old thinking and ideas. We must request that people proceed from the actual conditions in our country, that they respect objective laws, and that they undertake repeated and arduous examination so that we may be able to establish an allocation system that impels science and technology to be closely linked with the economy, that we may be able to establish a set of operational regulations for science and technology that has Chinese characteristics, as well as to allow us to gradually get onto a good circulating track.

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CSO: 40082034

NATIONAL DEVELOPMENTS

PROBLEMS FOR YOUNG, MIDDLE-AGED S&T PERSONNEL DISCUSSED

Beijing ZHONGGUO KEJI LUNTAN [FORUM ON SCIENCE AND TECHNOLOGY IN CHINA] in Chinese No 1, Sep 85 pp 54-56

[Article by Jin Luzhong [6855 1462 1813], Zhang Wenrun [1728 2429 3387], Xu Jiayuan [1776 1367 6678], Hong Jialan [3163 1367 5695]: "A Survey of the Situation Regarding Young and Middle-aged Scientists and Technicians"]

[Text] Not long ago, we conducted a preliminary survey of the situation of young scientists and technicians in Beijing, Guangzhou, Shenzhen, and Shanghai.

I. The Importance and Seriousness of the Problem

Based on statistics from the end of 1983, among the nearly 7 million scientists and technicians in the natural sciences, those of middle age (36-55) constitute 56 percent and the young (35 and below) make up 41 percent, which is a total for the young and middle-aged of 97 percent. Among academic leaders and persons of technical responsibility, the young and middle-aged constitute the majority. Based on a survey of some scientific and teaching units in Guangdong Province, the young and middle-aged were 95 percent, and even within the Chinese Academy of Sciences, with its larger proportion of older scientists, among 6,000 project directors, young and middle-aged scientific and technical key members were more than 80 percent. In the period from 1978 to 1983, among the primary scientists and technicians for projects awarded prizes for invention, the young and middle-aged comprised 89.7 percent. It can be seen that not only are the young and middle-aged great in number, but that they are in positions of responsibility and have made great contributions. This generation of young and middle-aged scientists and technicians has already become the mainstay of China's scientific and technical contingent, and they are fulfilling the historical task of forming a link between the past and future, and of making China's science and technology prosper.

Currently, there are two prominent problems among the contingent of young and middle-aged scientists and technicians: the health situation is not good. A survey of several units has shown that the death rate among young and middle-aged scientists and technicians is about twice that of older people. The Academy of Sciences has provided the following statements: "The older

generation holds longevity meetings, while the middle-aged hold memorial services," and "Middle-aged intellectuals are an attractive commodity at a reasonable price, but do not stand up to use." Because of this, some comrades have called out for "saving" the middle-aged scientists and technicians.

The other outstanding problem is that there is a "talent fault" lying beneath scientists and technicians. As apparent in the 26-35 age group, the amount of talent in both absolute and comparative numbers is small, and quality is lacking as well. Taking Shanghai as an example, in the 41-50 age group in this city, 51.5 of every thousand are college graduates, while among the 26-35 age group only 5.6 of every thousand have graduated from a college, which is a difference of more than 9 times. Looking from the point of view of absolute numbers, there are 65,000 of the former and only 14,700 of the latter, a difference of more than 4 times. The trough in population numbers is the crest in numbers of talent, which comes in the middle-aged group; and at the crest in population numbers is the trough in numbers of talent, which appears among the youth to constitute a "talent fault," or what some have called a talent crisis. Moreover, in another 10 years or so the problem will become more serious. The situation throughout the nation is like this. Therefore, there is also the problem of "saving" the young scientists and technicians.

II. Major Problems Among Youth Regarding Maturity and Fulfilling Their Roles

At present, outstanding scientific and technical talent is maturing slowly, and it is difficult to break out. According to a sampling and survey by the China Science Association, only one-fifth have carried out their functions well, three-fifths have partially done so, and one-fifth has not done so at all. The primary obstacles affecting complete fulfillment of their roles and maturity are:

1. Low scholastic positions. This is evidenced primarily in the fact that at every level of scholastic and technical leadership and review structure, the older generation of scientists are more numerous and the young and middle-aged rather less so. The problem of increasingly older scientific and technical leaders is far more serious than among party and governmental cadres, and the problem of the aging of knowledge is also rather severe. A considerable portion of people have been away from their specialties for many years and are actually laymen among professionals, which makes it difficult to do evaluations within the profession. Also, titles of professional and academic posts are not commensurate with the levels, abilities, and contributions. Abroad, instances where people in their 30's, and even those in their 20's, are professors or otherwise well known can be found everywhere. The older scientists in this country at present were also, for the most part, already professors or researchers in their 30's. But the situation at present is that there are 80,000 high-level specialists among natural scientists, among whom 51 percent are of the older generation. Only 1.65 percent of the total are 45 or under, and only 26 people are 35 and under, most of whom have come back to live from abroad. A great number of accomplished young and middle-aged key scientific personnel who have made contributions and are of a reasonable level, are still in middle grade posts, which has seriously suppressed their enthusiasm. Third, young and middle-aged scientists and technicians are without academic authority. For example, a number of middle-aged researchers

who are actually guiding the work of graduate students cannot be called graduate student advisors, and even those who abroad could guide the work of Ph.D. students cannot do so when they return home. And those who do guide the work of graduate students seldom personally do research work because of commitments throughout the year. The phenomenon whereby older scientists are given the credit while middle-level personnel are incidental is rather common in some units. In addition to this, "inbreeding" is rather serious, which has stifled the academic atmosphere. At some higher-level institutions, there are 4 and 5 generations of relatives, and younger and middle-aged scientists and technicians seldom have the atmosphere to make themselves known freely or to participate equally at academic conferences. This is especially true at the old-line colleges. Based on November 1984 statistics from Zhongshan University, among those teachers of the department of chemistry who graduated after liberation, 86.1 percent were graduates of that department in previous years, and in the analytical chemistry teaching and research section of that department the percentage of previous graduates is 96.6 percent. Because of this, they cannot develop the benefits of "cross fertilization," and new thinking is difficult to circulate, which even suppresses the maturation of outstanding talent.

2. Work responsibilities are heavy, and living conditions are deficient. Young and middle-aged scientists and technicians are currently carrying a great responsibility in our four modernizations, and will be decisive in it, but it is still such that at the age of 40 or 50, salary is 80 or 90 [yuan], there are one or two children, they are taking care of both their older generation and their younger, their responsibilities are great, living space is small, and it is hard to bring their energies and time to bear on their work. Difficulties in living are primarily manifested in low wages and cramped living conditions. According to the most recent statistics from the Chinese Academy of Sciences, among the 40-50 year old middle-aged scientists and technicians who currently have the greatest responsibilities, 80 percent have salaries from 78-89 yuan, which when you consider subsidies and total bonuses is lower than the national per capita monthly income of 47 yuan based on population averages. The wages of middle-aged intellectuals at research units and higher-level institutions is largely similar. The wages of younger scientists and technicians is even lower, and those college graduates who began school during the "cultural revolution" are currently earning about 56 yuan. Living space is not just a living condition for intellectuals, but is also a component of working conditions, as it is a place where mental efforts continue or deepen. Among the more than 30,000 scientists and technicians sampled and surveyed by the China Science Association, 64 percent demanded resolution of the housing problem. There are nearly 1,000 households where current per capita living area for scientists and technicians in the Beijing region of the China Academy of Sciences is not 3 square meters, even for three generations living together. Because work responsibilities are great and living conditions deficient, the physical conditions and states of health for middle-aged scientists and technicians are going down. According to a survey by the Chinese Medical Association of 11 units in Beijing, 81.6 percent of middle-aged intellectuals have some sort of chronic illness, which is higher than that of staff workers of the same age. The phenomenon of the early

deaths of the middle-aged is especially frightening, and has given rise to the scene where "the old send off their young," which has attracted the concern of many.

Since the 3d Plenary Session of the 11th CPC Central Committee, there has been a full scale attention paid to implementing policies toward intellectuals, which has won the deep gratitude of intellectuals. After several wage adjustments, the economic difficulties of middle-aged intellectuals have been alleviated. Some young and middle-aged have reacted with "the policy has been carried out for 70 and 80 year olds, while the burden has fallen on the shoulders of those with wages of 70 and 80 yuan a month," and for young and middle-aged intellectuals "there has been no end to good talk, but little good action."

3. Structures and systems are not conducive to competition, and lack internal motivation and pressure. Of the three major problems in this regard, one is that with management of scientists and technicians by party and government cadre, and unified distribution and assignment, scientists and technicians cannot move reasonably around. College graduates and graduate students who are assigned "according to need" never see each other, employing units cannot choose the best or be selective, "one is first married, then falls in love, and one's assignment determines the rest of one's life." Many units cannot meet their needs in talent and repressed talent cannot get free, which has given rise to a repression of talent in some units and a serious lack of personnel in others. Nor are high, middle, and low level personnel structures reasonable. A second problem is that the wage system currently in place cannot serve as an economic lever. There is no close connection between the quality of a scientist or technician's work and his material benefits, which gives rise to scientists and technicians "eating out of the same big pot." A third problem is lack of a set of science testing methods, a system of rewards and punishments, and a system and measures for encouraging talent to be top quality. Scientists and technicians lack internal motivation and pressure, and a "thousand li horse" would find it difficult to make much impression. At the opposite end is Shenzhen, where wages are not by age and there is strict testing, where people are obtained based on their abilities and contributions, where people are naturally put into competitive environments, where a group of young people and assistant engineers in their 20's and 30's have made quick progress, and where talent can show itself. A fourth problem is that the retirement system for scientists and technicians is imperfect, and in some places only middle levels and below are subject to retirement, which leads to the extraordinary phenomenon of "the daughter-in-law has retired, but her father-in-law has not."

4. Much is made of utility, little of training, knowledge has become obsolete, and retraining is lacking. In the world today, science and technology moves forward in leaps and bounds and the periods before obsolescence are getting shorter and shorter. The current problem is that the tendency to not pay attention to continuing education is rather serious. According to our preliminary survey of 32 units in Beijing, Guangzhou, and Shanghai, most units simply do not carry out the 3 to 6 month vocational refresher period every 3 years as provided for in the "Provisional Regulations for Cadre Management of Science and Technology" as issued by the Office of the

CPC Central Committee and the Office of the State Council. Training and education of youth in the fault has not received sufficient attention, and it has not been recognized that this is a strategic problem that concerns the four modernizations. Many have adopted an attitude that discriminates against and avoids those who graduated from college during the "cultural revolution," even to the extent of removing teachers or research positions, which has greatly undermined their self respect.

5. The influence of "leftist" ideology, old traditional concepts, and bad habits. For some departments and units there is really no solution for their dislike of talent. The outworn concept of revering the "head" and not the "family" is rather widespread. Sectarianism among scientists and technicians, disdain between literary people, and those who envy the worthy and are jealous of the capable have made it difficult for young and middle-aged scientists and technicians to fulfill their functions because of the "thick barrier" they create, which is not beneficial to reaching maturity. This is especially so for top notch talent that is thwarted by being talked about behind their backs and of whom perfection is demanded. It is even harder for these people to break through the barriers.

III. Suggestions for Accelerating the Maturation of the Young and Middle-aged and for Fulfilling Their Functions

1. Improve the academic and political positions of young and middle-aged scientists and technicians and encourage them to "establish their reputations as authorities." Among members of academic authoritative structures (degree holder's committees, professional evaluation committees, science fund evaluation committees, and awards committees), strive to have at least half be the qualified young and middle-aged. Members of these scholastic organizations are not in principle apart from the first line of research (teaching and production), and all who have been away for from 3 to 5 years and more should all go back into their academic organizations. With depth in their specialty, those young and middle-aged scientists and technicians who are suited to exploitative work in science and technology should be entrusted with the more important scientific and technical topics. Those who have quickly matured in actual practice and become leaders in the various scientific and technical fields should not be forced to assume administrative leadership. In evaluation of technical posts, scholastic and specialist levels and the extent of contributions should all be taken into account. For all primary scientists and technicians involved in science and technology achievements that receive national prizes for creative inventions, natural science awards, and scientific and technical advancement awards, for all those who in the past few years have been awarded the doctorate either here or abroad or who have made great accomplishments after so many years of actual scientific or technical work, for all those who have published academic papers of high quality in recent years, and for those who have been recognized by specialists in their fields, both here and abroad, as well as those scientists and technicians of a certain level who have actually guided the work of graduate students in recent years, be their qualifications and record of service greater or lesser, the problems of these people regarding promotion to higher posts should be considered foremost. Abolish the nominal system for guiding graduate students. Those accomplished and capable young and middle-aged people who have actually prepared and guided graduate students ought to

be qualified and authorized to guide graduate students in name. We should establish a young person's achievement award to encourage the young to make the most of their talent. Under working conditions, we should select the best and support a group of young and middle-aged scientific and technical core elements of attainments and who are outstanding, to allow them to mature as quickly as possible.

2. Implement a principle of allocation according to labor, the more done, the more one gets, and better work gets more. The recent restructuring of wages took this into consideration and recommended that from now on in further study of the principles for research wages, we should give full play to the important lever of wages. We will make the problem of housing conditions an important part of implementation of the policy toward intellectuals. We will make changes in the unreasonable phenomenon of "the more one studies the later housing is made available and the smaller the area." When housing is available, scientists and technicians should be considered first, especially those middle-aged scientists and technicians who most need housing, and we will strictly carry out the provision that one's years out of college will be one's standing regarding the availability of housing. For those who have made great contributions, better living conditions should be provided. All housing erected for use by intellectuals should be guaranteed for use by intellectuals.

3. Strengthen intellectual development, and pay attention to the promotion and cultivation of talent. On the basis of universally improving the quality of scientists and technicians, the focus will be to pay close attention to two types of people: one is that in selecting and cultivating top notch talent, make them into scientific and technical leaders; second, earnestly solve the "fault" problem in the scientific and technical contingent to ensure that science and technology has another generation.

We should strongly enhance the cultivation of graduate students because this will be the primary source of high-level talent, and entry level posts will eventually be filled by graduate students. We will break up departmental boundaries and permit employing units to come into higher institutions for recruitment 1 and 2 years before graduation, and at the same time will allow graduate students the right to choose their unit, allowing "provided as needed" to be faced earlier and to determine the direction of training. Encourage the young and middle-aged to go out of the country to earn their degrees and for advanced study, and for those leaving the country to participate in international conferences, or in cooperative research, or to teach, as long as the sponsor is providing funds, all sorts of excuses should not be found for keeping that person in this country. Technical examinations should focus on scientists and technicians.

We should respect the training of scientists and technicians already at work, and in addition to holding back on responsibilities, should also provide the opportunity for advanced training. We must formulate the "Rules for Continuing Engineering Education for Scientists and Technicians" as quickly as possible to allow systemizing continuing engineering education. Leaders at all levels should have a strategic view toward ensuring the time and

conditions for refresher training. For that talent concealed in the "fault," we should adopt decisive "saving" measures. If we are to view them properly ideologically, we definitely cannot shun them but must warmly help them, and adopt various ways to vigorously cultivate them. Those who can benefit should likewise have the opportunity to go abroad for advanced study and to strive for academic posts.

4. Restructuring the management system for scientists and technicians will allow the outstanding young and middle-aged to break out from under. The core of this problem is in putting a hiring system into effect to accelerate the reasonable movement of talent and to permit academic leaders the "freedom to organize reviews," and create an environment of selection through competition. Economic policies relevant to the movement of talent should be complete and should allow the state, groups, and individuals to compete on the same basis. "Cross breeding produces superiority," so promote occupational exchanges between units, and especially between research units and higher institutions, to quicken the maturation of talent. At the same time, we want to break up the traditional habits of "inbreeding" and of "several generations employed together."

5. Continue to eradicate the influence of "leftist" ideology, further rectify understanding of intellectual labor and scientists and technicians, and overcome the worn out ideas that salary is according to age and that the "head" is to be valued over the "family." We should create a good atmosphere of warm-hearted support in society.

It is our belief that as long as we respect the maturing of young and middle-aged scientists and technicians and conscientiously solve certain practical problems, then a situation will persevere whereby talent appears each generation and where science and technology flourish and develop.

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CSO: 40082022

NATIONAL DEVELOPMENTS

SUGGESTIONS FOR OPENING S&T TECHNOLOGY MARKETS PRESENTED

Beijing ZHONGGUO KEJI LUNTAN [FORUM ON SCIENCE AND TECHNOLOGY IN CHINA]
in Chinese No 1, Sep 85 pp 48-50

[Article by Guo Shuyan [6753 2885 6056]: "Vigorously Open Up Technology Markets, Push Forward Restructuring of the Technology System"]

[Text] The resolution by the CPC Central Committee regarding restructuring of the science and technology system is yet another grand strategic policy following upon the resolution to continue restructuring the economic system. The central link in this science and technology system reform is that it will change the situation that has been in effect for years now in which the rights to scientific and technical achievements are transferred without compensation, where topics selected for research are not directly related to markets, where there is a situation that creates barriers, where the military and civilian are separate, where the state controls everything about research organizations, and where scientific research is divorced from production. If we are going to allow science and technology be able to effectively serve economic construction, then we must allow the achievements of technology to become commercial and vigorously open up technology markets.

I. The Importance of Opening Up Technology Markets

To carry out the commercialization of technical achievements and open up technology markets, we must change to a great degree the operational regulations for the technology system. First, it will hasten developments in technology. Research organizations will determine research topics based on the market and the needs of society, even to extending applications. This changes the situation of the past that was purely tasking passed down from above, and will impel scientists and technicians to earnestly seek out, study, and solve technical problems in building production, will enhance motivation, and will also cause science and technology to be closely integrated with economic construction. Second, it will drive research units to consider technology development together with its contributions to social and economic construction, and together with their own economic results. This will consequently increase the impetus and activity catering to economic construction. Third, the objective reality of market competition will spur on research organizations and scientists and technicians that engage in development, and it will improve personal work efficiency and vocational

standards. It will urge them to produce more results, produce better results, and to change their own results into production forces as quickly as possible. Fourth, a consequence of commercializing technical achievements is that whoever asks for something puts up the money; whoever buys something pays a fee. This will of course break up the boundaries that have existed for a long time between different levels, departments, regions, and the military and civilian sectors, hastening the socialization of science and technology. Fifth, opening technology markets will free the broad mass of scientists and technicians from the bonds of the old regulations, will stimulate their enthusiasm for invention and creation, and will provide an expanded arena of practice for all those who are competent and willing to research and for those who have come to their talent through self study. At the same time, it will urge talent and knowledge to move reasonably with the transfer of rights to technology. Sixth, through the exchange and application of technical products, their actual value will be fully evident. This will rid us of the old idea that "knowledge is not worth money," and will form an excellent social atmosphere that respects knowledge and respects talent.

II. New Trends in the Development of China's Technology Markets

Technology as a commodity already has a 2,000 year history abroad, and the modern day world technology trade has an even more unprecedented vitality. In China, the entrance of technology into the marketplace is an event of only the last few years. But there has been great life in it since its appearance there, and it has quickly entered a new stage in terms of content, form, scale, and pace as it develops in breath and depth. The trade fair for transferring military industrial technology to civilian use held in March this year in Hangzhou and the first national technology achievements trade fair are obvious proofs. We can see from these two trade fairs characteristics of the new trends in the development of our technology markets.

1. Some projects from planning have begun to enter the technology markets. Of capital construction, renewal, and key projects from provincial, municipal, prefectural, and county planning, 22 have entered the market as transactions for official contracts at amounts reaching above 10 million yuan, and 134 are for over 1 million, both of which together account for 88 percent of total transactions. The city of Danjiang in Hubei originally planned to invest 27 million yuan to erect a Chinese alpine rush pulp mill, but because they could not select the appropriate technology they put off starting for several years. But at the trade fair, they finally reached a technical agreement with the Hangzhou Office of Light Industry Machinery.

2. The number of items under engineering general contract (keys of exchange) has greatly increased. At the trade fair for technology achievements, many purchasers demanded to be provided with entire packages of technology, and 320 contracts were signed for 1.74 billion RMB, which was 60 percent of the business done. This did much to promote horizontal relations among the selling units, and provided a new path for improving the organization and implementation of planning projects. As for example where the Yaojie coal mine of Gansu signed a general responsibility contract with the Ministry of Light Industry affiliated Jingde Ceramic Research Institute, the Changsha Light Industry Design Academy, and the Light Industry Machinery Manufacturing

Company to use the coal mine's coke-oven gas and the abundant local pottery clay resources to produce colored facing brick and ceramic products. The responsibility contract included the whole process, from feasibility studies, ceramic techniques, engineering design, equipment manufacture, installation, debugging, to personnel training, for a total investment of 32 million yuan.

3. Import projects have entered trade fair bidding. As for example when the Liaohe Sweet Chrysanthemum Products Factory had originally planned to use 1.9 million U.S. dollars to import a sweet chrysanthemum glucoside production line from Japan. At the technology achievements fair, they discovered that the techniques and technology from Nankai University were both better than that of Japan, and they concluded this transaction for only 380,000 RMB. This sort of method that discovers domestic technical potential and saves on foreign currency is well worth our attention.

4. Use of the technology shareholding format. The transaction method by which scientific research units and enterprises jointly develop and jointly operate has been welcomed. At this technology achievements trade fair, about 18 percent of the transactions used this method. It can both alleviate funding pressures on the purchaser, giving the enterprise a long-term, stable technical basis, and can also allow research units to have a long-term, stable source of funding. Both parties to the shareholding share the risks and both parties share the benefits. The 8-year joint contract for the development of new plastic materials signed by the Beijing Chemical Engineering Research Institute with the Shangyu Plastics Factory of Zhejiang used just this format.

5. Applicable technical equipment has been welcomed. A large quantity of inconspicuous technology was welcomed by small and medium-sized enterprises and township and town enterprises, and according to statistics made up 60 percent of all projects at the trade talks and 38 percent of the total value. Small contracts under 100,000 yuan constituted 3.5 percent of the total values, while the number of such contracts were 83.3 percent of the total contracts. From the point of view of the number of projects transacted, the six liveliest professions were light industry, foodstuffs, and building materials, with petroleum engineering tied with machinery and electronics.

6. Banks and financial circles entered the technology markets. At this trade fair for technical achievements, some banks at the provincial and regional level, like Hunan, Hebei, Hubei, Fujian, Jilin, Shaanxi, and Shanxi, supported local transactions for projects with loans from several million yuan to several tens of millions, and they provided experience for science and technology circles, production circles, and financing circles. According to statistics from Hutan City, the development for which they used funds and credit to support advanced applicable technology has produced excellent results. For each yuan of circulating funds or credit, they gain 0.44 yuan per year, loans for equipment gain 0.77 yuan, while loans for technology development gain 3.43 yuan.

III. Principles, Policies, and Measures for Opening Up Technology Markets

The current principle is that we will further open up and invigorate in terms of policy, and the state, groups, and individuals may join together to develop the technology trade through hierarchical, multi-channel, and varied formats.

Not long ago, the State Council approved the establishment of a guiding small group to coordinate the national technology market, with the National Science and Technology Commission as head, and with the cooperation of the National Defense Science, Technology, and Industry Commission, and composed of 11 units from the Planning Commission, Academy of Sciences, Ministry of Education, Science and Technology Association, the Federation of Trade Unions, the Ministry of Finance, the Patent Office, the Office of Industrial and Commercial Administration and Management, the Bureau of Statistics, the Bank of Industry and Commerce, and the Office of the Science and Technology Leading Group. This group is charged with organizing forces, with macroscopic guidance of the technology markets, with formulating relevant laws and regulations, with linking data from various areas, and with expediting the development of the national technology markets. Recent tentative working plans by the coordinating group are: to arrange work on the technology markets over a few years time and to put it on track for adapting to the needs of the science and technology system and the economic system. Particular preparations will begin in the following aspects:

1. We will gradually set up and perfect the laws and regulations for the technology markets. Work out such things as management methods for the technology market, technology contract laws, ways to promote technical achievements, and a provisional statistics system for the technology trade. We will adjust some policies and regulations issued in the past that are not in tune with or are not coordinated with opening up technology markets; and will rectify as quickly as possible mishandling of technicians in the past regarding these areas.
2. We will formulate strong supporting policies and measures in the areas of pricing, tax revenue, credit, and allocation. According to the resolution by the Central Committee regarding restructuring the science and technology system, the state will not restrict pricing for the transfer of rights to technology, there will be market regulation, and it will be as determined by both parties to transactions. Income from the transfer of rights to technology will not be taxed for the near term. When selling new products, there will be a certain period of reduced or exempted taxes. Banks will use various forms of credit to support the technology trade. The state encourages scientific research units to undertake joint operations with industrial and mining enterprises on the basis of technology shareholding. To stimulate the enthusiasm of the three parties that are the buyer, seller, and middleman, their legal rights and interests will be guaranteed, and in profit retention and allocation we will handle carefully the relations between the state, groups, and individuals. In the situation where scientists and technicians are working at their own jobs, but where they use time apart from their work to deal with technical development and technical service to make additional contributions to the state and to society, this is a good thing that benefits the state and enriches the people, and the compensation that they obtain

through their arduous efforts in only right. This will also impel some research units to quickly improve their work from the management point of view.

3. To spur on the most rapid prosperity for the technology markets, we will reform our own work in the three aspects of development, acceptance, and intermediaries. Technology development units will gradually change from the pure "planned research model" to the "research operations model," they will establish market concepts, will strengthen their competitive consciousness, and will set up and perfect operational structures for technical products. Outside of the unit, there will be compensated transfer of the rights to technology, and within there will be research topic responsibility, which will be freely constituted by personnel themselves. They will continue to improve the quality of personnel to react sensitively to complicated and changing social needs and to allow themselves to have the capacity to absorb foreign advanced technology, the capacity for self-development, and for self-renewal. Based on market surveys, market analyses, and forecasted demand, they will integrate their own characteristics, will formulate operational strategies for their own departments, and will determine and adjust development directions to better continuously select technical products that are competitive to supply to the technology markets. They will change the old situation whereby development work remained at the level of samples and exhibits, where technical achievements had to navigate through technical and economic passes, and they will solve the problem of packaging single technologies. They will not only solve the problems at the research, design, and trial production stages, but also will solve the problems of broadened applications, batch production, and exchange. They will become good at developing their own strong points, as well as at coordinating each faction and implementing all forms of alliances.

4. We will establish our own comprehensive trade system. We will maintain and support various organizations for technical exchange, trade, consulting, service, information, and certification. We must change the traditional idea that despises operational work, and will train and build up in actual practice a group of talented people with an aggressive spirit who both understand technology and know about operations. We will allow them to become the advertisers of the new production forces, and will reward those with outstanding accomplishments.

5. We will establish an unobstructed market information network, and properly manage the work of market statistics and forecasting. We will use modern methods to manage the gathering, dissemination, and inquiry into market information, will pay close attention to the tool that transmits data-- the newspaper, will run a newspaper the likes of TECHNOLOGY MARKETS, and will increase the amounts of our information. Each province and municipality will gradually establish and perfect their own technology information networks based on their own conditions.

6. Based on the two interrelated technology markets, international and domestic, we will become good at using two kinds of resources, and will learn how to use two sets of skills. We will absorb and import advanced foreign technology in order to advance the starting points of our progress forward.

At the same time, we will also develop, innovate on, and improve our level of technology through absorption and assimilation. At the same time as we import, we will also become good at using tariffs and administrative methods for a limited but necessary amount of protection for the domestic technology markets.

7. We will organize Chinese technology market research associations to further the theoretical study of technology markets. The questions of the value and pricing of technical commodities, and policies for distributing the income from transferring the rights to technology would be examples.

8. We will enhance the vitality with which enterprises absorb and develop technology. We will politically support and encourage enterprises in their use of new technology and in their development of new products; and we will provide support in the areas of funding, pricing, taxation, credit, inspection, and encouragement. We will gather our energy to develop sets of technology, to provide packages of equipment, and to change imported technology into our own technology. We will practice nationalization, and will work toward providing whole sets of technologies for the technology marketplace. Currently, those most urgently in need of technology are the town and township enterprises, deficit enterprises, and the small and medium-sized enterprises that are weak in technical capacity. Medium- to large-sized key enterprises would appear not to be in such urgent need of technology, but this is a temporary phenomenon. As restructuring of the economic and science and technology systems develops more deeply, the needs of medium- to large-sized enterprises will be constantly alive, and a technology market with even higher technical requirements and even greater capacities will develop before our eyes.

Carrying out the commercialization of technology and developing technology markets are completely new events. On the one hand we want to free up our thinking, be bold in opening up, and courageously put this into practice; on the other hand, we want to proceed from reality, investigate and study, give meticulous guidance, and constantly discover and resolve new problems that appear as we progress to allow us to develop healthily. It may be believed that unprecedentedly broad and prospering technology markets are certain to erupt throughout the country to impel the development of China's science and technology and its economic construction.

12586

CSO: 40082022

NATIONAL DEVELOPMENTS

FUJIAN SCIENTIFIC INVESTMENT INCREASED 32.8 PERCENT

Fuzhou FUJIAN RIBAO in Chinese 9 Nov 85 p 1

[Article by Lai Jian [0171 7003], Si Huai [1835 2849] and Sun Yuan [1327 0626]: "Fujian Shifts the Focus of Scientific Advance toward Production"]

[Text] After adjustments, the scale of technical advance projects in Fujian's enterprises has returned to normal and the projects are proceeding satisfactorily. This was disclosed at the provincial report meeting on technical advance in the industry and trade sector which closed on 31 October. From last January through September, a total of 315 million yuan was invested in technical advance projects by industrial and transportation enterprises owned by the whole people, including technical modernization, import and technical development projects. That figure represents an increase of 32.8 percent over the corresponding period last year.

Since early this year, our province has been shifting the thrust of technical advance work toward putting projects into production and increasing economic results. Toward that end, we have been closely coordinating moves and cooperating with one another to solve practical problems. The provincial Economic Commission estimates that this year we will be able to complete 70 technical modernization projects using domestic equipment, 12 more than last year, each with an outlay of more than 1 million yuan. We will also be able to complete 120 technical modernization projects using imported technology, 16 more than in 1984. In addition we will come up with 200 high-grade products and adopt 130 international standards. Of the 165 new products listed as national and provincial new products, so far 109 have been put into production, and of the 64 new technology popularization projects, 54 have been completed.

12581
CSO: 4008/2049

NATIONAL DEVELOPMENTS

ON SCIENTISTS AS ENTREPRENEURS

Tianjin TIANJIN RIBAO in Chinese 12 Nov 85 p 4

[Article by Xia Zuoyun [1115 0155 0061]: "More Scientists Should Combine Research with Business Management"]

[Text] The "Proposals of the CPC Central Committee on the Formulation of the Seventh 5-Year Plan on National Economic and Social Development" point out, "We must fully realize the decisive role scientific modernization plays in the four modernizations and further implement the principle that economic development must rely on scientific and technological progress, while scientific and technological work must orient itself toward the economy." To carry out the CPC Central Committee's "Proposals" conscientiously, scientific and technical workers must delve into production realities and conduct scientific research from the starting point of the needs of a developing economy. In addition, we need a host of scientists personally going in for entrepreneurship.

The scientist qua entrepreneur is a well-established phenomenon in foreign countries. The contributions of many famous scientists sprang from their combining science with entrepreneurship. Apart from being a great inventor with over 300 patents to his name, the world renowned Alfred Nobel was a superb industrialist, a commercial genius who knew how to run a business. Celebrated as an industrialist as well as scientist, he moved easily between the two worlds of science and business and pioneered several enterprises. Almost to a man, the founders of knowledge-intensive companies in the well-known Silicon Valley and Gene Valley are scientists: Hewlett-Packard, Apple Computers and Intel Corporation were all started by scientists doubling as entrepreneurs. Many scholars in the United States are also highly accomplished industrialists.

In China, too, numerous scientists have been involved in industrial development. Hou Deban [0186 1795 2831], the famous chemist, founded "Yongli Chemical Co" to market his technology and became a pioneer of China's modern industrial chemicals industry. Prof. Mao Yisheng [5403 0110 0581], the well-known contemporary specialist in bridge construction, is now concurrently manager of the China Bridge Co. Biologist Tan Jiazen [6151 1367 2823], 76, recently became chairman of the boards of Universal Biological Co and Yangzi Optical Co. Today more than 100 people at the Shanghai Institute of Silicate

Research, Chinese Academy of Sciences, are hired by enterprises as consultants or technical advisers. Some hold concurrent posts as deputy director and manager. A group of modern experts who are proficient in production and management as well as scientific research is emerging. In the torrent of reform, they are demonstrating their diverse talents as scientists and enterprise managers and fast becoming key players on the stage in society.

Division of labor is a sign of social progress, but when division of labor becomes fragmentation, it does not help production development. In the past, some scientific and research workers seldom concerned themselves with the production side of an enterprise, severing arbitrarily scientific discovery and technical invention from production and application. As a result, the application of scientific research achievements was held up and their conversion into productive forces failed to materialize. Comrade Deng Xiaoping once said, "Now we must further resolve the problem of integrating science and technology with the economy." He also said, "Increase our productive forces." One of the best ways to integrate science and technology, on the one hand, and the economy, on the other, is to have scientists interested in entrepreneurs and doubling as entrepreneurs.

There are many unique advantages about scientists engaging in industrial development. First, as scientists, they are better equipped to strengthen enterprise management, adopt new technology to modernize old plants, old products and old technologies, speed up the transfer and dissemination of new technology, improve the standard of production technology, and accelerate the conversion of scientific achievements into productive forces, thereby stimulating economic growth. Second, when they double as industrialists, scientists get more opportunities to come into contact with the real world of production, understand market information more promptly and obtain feedback on scientific research work. Such feedback itself constitutes a test of their scientific achievements, which benefits the further development of science and technology. Accordingly, we should encourage some scientific and technical personnel to plunge into production practice with enthusiasm and get involved in industrial development. In the process we will transform scientific research from a closed world into a totally open system, thus furthering the principle that economic work must rely on science and technology and scientific work must orient itself to economic construction.

This article of course does not mean to suggest that every scientific and technical worker should go into industrial development. It only hopes that scientific and technical workers with an aptitude for business management will make full use of their intelligence and talents and play an active role in industrial development to promote the integration of science and the economy and make fresh contributions to the four modernizations.

12581
CSO: 4008/2049

NATIONAL DEVELOPMENTS

SHANDONG REFORMS SCIENCE, TECHNOLOGY FUNDING SYSTEM

Jinan DAZHONG RIBAO in Chinese 6 Nov 85 p 4

[Text] Shandong Province has begun to reform the science and technology appropriations system by first tackling the three ways in which science and technology funds are managed.

In recent years, departments concerned at various levels in our province have all stepped up investments in science and technology. This year provincial appropriations went up 59 percent compared to 1980, while local appropriations rose almost 1.2-fold over 1982. To increase the social results of science and technology outlays, the province in the past few years has reformed in three ways the way we manage science and technology funds. First, signing project contracts to ensure that funds are paid back. Specifically, in the case of a priority project, the Science and Technology Commission, the unit which undertakes to do the project, and the department in charge are all parties to a contract. In the case of a regular project, the contract is signed by the department in charge and the research unit concerned. The department in charge supervises the use of project funds, ensures that funds are recouped and re-plans their use. In this way, the initiative of the department is further mobilized and management strengthened. Second, using credit as an economic mechanism. In the course of planning the second batch of planned projects this year, for instance, the provincial Science and Technology Commission set aside a portion of the funds as a science and technology development fund. Specialized banks loaned the funds to units in accordance with contract provisions and were also responsible for collecting them later. Consequently, of the 77 new projects, 37 were financed by loans and only 26.9 percent of the new projects' financial requirements consisted of straight grants. Third, in line with the spirit of simplifying administration and decentralizing power, the Science and Technology Commission offered some funds to help prefectures, counties and municipalities set up science and technology development funds, thereby almost doubling its appropriations this year compared to last year. To make sure the funds are well managed and put to good use, some prefectures and municipalities have come together to improve science and technology planning and adopted the "four synchronizations," namely, synchronizing the two kinds of planning, command and guidance; synchronizing municipal (prefectural) investments with county (municipal) investments; synchronizing funding management by the Science and Technology Commission with that by the banks; and synchronizing the contract system with the contracting system. The results of these measures have been very good.

As their effort to reform the funding system of scientific research institutes, the province, municipalities and prefectures last year selected 42 relatively well-qualified research units as the laboratory of their experiment in the gradual abolition of state operating grants. So far there are 36 scientific research units which require absolutely no operating funds from the state. These units undertake projects for outside parties in return for a fee. Internally they follow a project contracting system and all manner of responsibility systems. Last year their total income exceeded 35 million yuan, up 29 percent over the year before.

12581
CSO: 4008/2049

NATIONAL DEVELOPMENTS

DEVELOPMENT OF GUANGZHOU TECHNOLOGY MARKET DESCRIBED

Guangzhou GUANGZHOU YANJIU [GUANGZHOU STUDIES] in Chinese No 5, 1985 pp 32-34

[Article by Zhang Jinzhi [1728 6930 2535]: "The Form, Characteristics, and Conditions for Development of the Guangzhou Technology Market"]

[Text] As a socialist commodity economy rapidly develops, a brand new market-- the technology market, is just now rapidly springing up and developing.

In early 1981, the Guangzhou Municipal Science and Technology Exchange Center and the Science and Technology Consulting Service Company were set up one after the other, and then in December of that year the first Guangzhou regional Science and Technology Achievements Trade Fair was held. Eighty-five units with 1,200 projects participated in the trade fair, including science and technology units stationed in Guangzhou and affiliated with the central authorities and the provinces, and from higher level institutions. During the period of the trade fair, more than 30,000 representatives of over 2,000 units came to the fair to look and talk things over, making transactions that reached 420,000 yuan in value. This was an important index for the Guangzhou science and technology market. Beginning at that time, technology trade activities, the primary components of which were developing the transfer of rights to technical achievements, technical service, science and technology consulting, and the exchange of talent, gradually began to build up throughout the city. Intermediaries for technical exchange, such as enterprises like the Science and Technology Development Company, the Science and Technology Exchange Center, the Soft Science Service Company, the Talent Development Company, science and technology street and science and technology shops, and science and technology consulting service companies, were established one after the other, and scientific and technical achievements and advanced technology began to enter the market as commodities. This fundamentally changed the situation of the past, where scientific and technical achievements and talent were owned by departments and locked into regions, and it changed the situation in which science and technology were divorced from production and where science and technology and the economy were two separate things, which consequently put new life into the development of science and technology and the economy in this city.

I. The Primary Forms of the Guangzhou Technology Markets and Their Characteristics

Currently, technology exchange in Guangzhou is through the following several types:

One is the soft technology trade market. This is primarily through various academic trade fairs and public lectures, as well as information materials and consulting services, to attain the goals of transmitting information, broadening knowledge, and mastering a technology. In particular there are:

1. Holding various forms of technology lecture courses and academic public lectures. This is an initial form of soft science exchange. The characteristic of this sort of exchange is that the scope is broad. In recent years, there were more than 700 foreign advanced technology lectures and academic public lectures sponsored by the Guangdong Provincial Science and Technology Commission and the Guangzhou Municipal Science and Technology Commission, to which more than 80,000 people from throughout the country have come to take part. The number of technical lectures and academic public lectures on domestic subjects had even more. Since 1980, the Guangzhou Office of Science and Technology Interchange has held 60 technology classes (including foreign languages and management) together with scientists and technicians from Hong Kong, Macao, and abroad, and with factories and stores, and has trained more than 11,600 students. The Guangzhou Academy of Chinese Medicine has been holding international acupuncture classes since 1980, for which more than 300 students have come to study from 45 countries and regions, among them Japan, the U.S., and Australia.

2. Developing various scientific and technical consulting services. Scientific and technical consulting services changed the situation where in the past groups would only take up academic exchanges, and where research units were divorced from production departments, which allowed science and technology to take some unfortunate steps as far as catering to production and to economic construction are concerned. According to incomplete statistics, there are currently 81 various types of scientific and technical consulting research organizations and consulting service companies, consulting service centers, and consulting service departments, 28 of which are full time consulting organizations and 53 are organizations that also offer consulting services. The subject matter for consulting services includes feasibility studies for technologies, equipment, and investment, and development, production and operations for new products and new technology. In 1984 more than 1,000 consulting projects were developed, which resulted in economic profits of more than 10 million yuan.

3. Sending scientists and technicians for observation and interchange. Through mutual observation and interchange there will be further opening of the channels of circulation for technical information, which has become a special component of the technology marketplace. For some years now, the provincial and municipal science and technology commissions have organized more than 40 groups with a total of over 2,000 people to go to Japan, the U.S., Australia, and Hong Kong and Macao for observation and study, at the same time greeting more than 400 groups visiting and interchanging from

foreign scientific and technical circles, for a total of more than 2,000 people. Even more have studied and participated in exchanges in various provinces and cities within this country.

4. Holding various information activities. All kinds of specialist books and newspapers and journals reflecting scientific and technical information have been published one after the other, and various information centers have also been successively established. Forty-two information networks (stations) have been set up for the science and technology information system that is centered on provincial and municipal science and technology information. This network has an intelligence contingent of more than 2,700 people, who provide a great deal of information materials for research and production departments. Through on-line retrieval by two large science and technology service organizations in Hong Kong and the rest of the world, computer terminals in Guangdong Province can quickly and completely provide science and technology information to scientific and technical and production units. This system has been in use for 8 months, during which time more than 4,000 people have come from throughout the country to use it, and it has provided more than 600 consulting services. The various specialist books published by Guangdong Provincial Science and Technology Publishing Company and other publishing departments, together with various publications established by all the technical schools and higher institutions, research departments, and academic groups have reached more than 300, with a total volume published in the millions each year. The Guangdong Provincial Science and Technology Library, the Zhongshan Library, and the Guangzhou Library, as well as the libraries (offices) of the various technical schools and higher institutions and the science and technology departments have more than 10,000 scientific and technical periodicals and millions of books on science and technology. The China Books Import Export Company, Guangzhou branch, has established long term professional relations with more than 8,000 publishing companies, bookstores, and academic research organizations in more than 100 countries throughout the world, to provide a scientific and technical book service both within and out of the province.

Second, are the hard technology markets. They carry on technical trade chiefly in the form of exhibitions of scientific and technical achievements, trade fairs, and cooperative trouble-shooting conferences. More specifically, they are:

1. Holding various exhibitions, interchanges, and trade fairs for scientific and technical achievements. Using these formats, higher institutions and science and technology design units can directly discuss cooperative projects with production departments, to more quickly reach agreements and sign scientific and technical cooperative contracts. As for example the first Exhibition and Exchange of Scientific and Technical Achievements held in the Guangzhou region in 1982, in which 85 higher institutions and research units participated, at which there were 1,292 technology achievements, and where there were more than 70 scientific and technical achievements and products registered as available for sale. During the period of the meeting, contracts were signed for the transfer of the rights to 15 of these.

2. Developing various domestic joint activities involving imports. Functioning through economic levers, these have crossed regional and department boundaries, allowing advanced science and technology to be transferred from science and technology units to production departments, from military to civilian use, from the coasts to inland, and from outside the country to within it. Based on incomplete statistics, from 1979 through 1984 there were 283 Chinese-foreign jointly funded cooperative projects and compensation trade contracts signed or contracted for throughout the city; there were more than 14,000 contracts for processing of imported materials and for assembly of imported parts; more than 150 production lines were imported, as well as tens of thousands of sets of advanced equipment; more than 1,300 contracts and agreements have been signed for economic and technical cooperation with enterprises and units from 21 provinces, cities, and autonomous regions, for a total investment of 390 million yuan; and 31 technologies have been brought in from other provinces and cities, 21 have been taken out, and 21 raw material bases were set up.

3. Organizing various scientific and technical project trouble-shooting conferences. In 1984, Guangzhou arranged 141 scientific and technical projects to tackle key problems, and more than 300 trouble-shooting conferences and demonstrations of all sizes have been held.

4. Setting up various scientific and technical trade organizations, like science and technology stores. At present, there are 343 technical service and trading organizations throughout the city, and 39 science and technology stores. These stores exhibit, market, and transfer the rights to new scientific and technical achievements, develop technical consulting services, undertake technical training and technical problem solving discussions, and also handle advanced foreign and domestic teaching instruments, medical instruments, computers, household appliances, and photographic materials. One street in the science and technology market attracted a large number of customers from both within and outside the province and business prospered, which promoted scientific and technical exchange and trade. After being open for less than 6 months business had already reached 9 million yuan, until at present daily business is more than 50,000 yuan.

Third, is an organic market. By this is meant chiefly expositions and trade fairs for various new products, new technology, new techniques, and new equipment. As for example the China Export Commodities Trade Fair held in Guangzhou, as well as the "Beautify Guangzhou" Fair and the Light Industry Products Exhibition Marketing Fair. New products emerging in a constant stream compete in the marketplace, which is actually competition in technology, and the products exhibited also reflect to varying degrees the technical level and real economic strength of China and Guangzhou.

II. Far Reaching Changes Brought by the Prosperity of Technology Markets

The appearance of science and technology markets struck out at various straightjackets that bound scientific and technical and economic development, they quickened the pace of restructuring the science and technology system, promoted exploitation and development of new technical fields, and accelerated economic prosperity.

1. They have raised the value of knowledge and technology, gradually forming an attitude in society that respects knowledge and talent. In the far-reaching technology trade, the value of technology has been acknowledged; intellectuals and mental labor has been honored, and this has caused the study of technology, pursuit of an education, and seeking after knowledge to be common practice throughout society. To meet the requirements of staff in seeking an education and studying technology, all professions and enterprises throughout the city have started up 548 on-the-job and technology schools, for which by the end of 1984 there were 380,000 staff students. Schools run by society have developed abruptly, and there are more than 160 supplementary and night schools with more than 50,000 students; 330,000 people have an supplemental education, have passed tests, and have attained junior middle school level educations, which is 61 percent of those throughout the city who take junior middle school supplementary classes; 250,000 people have tested to a level of high school, which is 69 percent of the staff taking supplementary classes.

2. Scientific research has been even more closely linked to production, and the rate at which the achievements of scientific research have extended to applications has improved everywhere. In 1984, 30 specialist research institutes affiliated with the city completed a total of 125 research projects, 87 of which were applied that same year, for an extended applications rate of 69.6 percent, which was 20 percent higher than in 1978.

3. Work efficiency in scientific research units has improved, economic income has increased, and research conditions have improved accordingly. In the past, a scientist or technician at the provincial electronics research institute took an average of 18 years to produce an achievement, while among the 15 projects contracted for in 1984, the project that took longest to complete needed only five people and 19 months. According to statistics, in 1984, 39 research institutes affiliated with the city had an income of 6.6 million yuan, which was nearly 3 times that of 1981, and was a 65.8 percent increase over 1983. In 1984, of 37 applications development institutes affiliated with the city, 21 have newly built laboratories to begin solving the problems of experimental sites.

4. Having cleared the channels of technology transfer, this has accelerated broad technical cooperation and economic integration. A large number of new achievements and new technologies have been exchanged in the markets, and have obtained clear economic and social results. As technical commodities circulate, joint cooperative relations of all sorts will be gradually established. According to 1984 year-end figures, throughout the city relations have been established with more than 200 technical and vocational schools, scientific research organizations, academic groups, factories and stores, and companies in more than 20 countries and regions, and internal joint cooperative relations have been established inside China with technical and vocational schools, research departments, and enterprises in 21 provinces, cities, and autonomous regions. Independent specialist institutes just within the city area have developed about 100 projects with 127 units from 18 provinces and cities for technical service, achievement rights transfer, and for selling new scientific and technical products.

5. They have promoted the reasonable movement of intellectual and scientific and technical talent. Since its inception in 1983, the Provincial Talent Exchange Center has worked as a "go-between" and a "bridge" in talent exchange, and by the end of 1984 more than 4,500 specialists of all sorts had gone to register, and more than 400 employing units had preliminarily selected some 1,300 people, among which more than 400 had already filed the paper work for transfer. At the 5-day Guangzhou Talent Exchange Fair held in August 1984, more than 8,700 people were requesting to move, 3,100 among which have already been preliminarily selected by employing units, and more than 200 had arranged for transfers not long after the fair.

III. How Can We Make the Guangzhou Technology Markets More Prosperous?

The work of opening up technology in this city has just begun, and there are still some problems needing urgent attention that will require earnest study for resolution.

1. Strengthen the macroscopic management and guidance of the technology markets. We must strengthen macroscopic management and guidance regarding development directions and scale of the technology markets. We will keep to the principles of opening up to reforms, equally and without discrimination and uniformly encourage and support technology markets, whether they are year-round or temporary, specialist or general, regional or departmental, or run by units or the masses, groups, or individuals. We will gradually establish and perfect a system of laws and regulations for technology markets, and will as quickly as possible formulate things such as laws for technology market management, management laws for scientific and technical cooperative contracts, scientific and technical consulting laws, and laws for the movement of scientists and technicians.

2. Enhance the research into technology market policies. Technology markets are a new thing in China, and in the process of their emergence and development many problems of a policy nature will require study. As for example the problems of technology product value, pricing problems, and allocation of income from the transfer of the rights to technology, all of which will require study and investigation both theoretical and practical. Banking, finance, and taxation departments will all draw up strong supporting policies and measures that will be convenient and preferential for technology markets, especially in the areas of pricing, taxation, credit, and distribution. As for those policies and provisions that had been promulgated before and are not in keeping or coordination with opening up technology markets, they should be quickly adjusted. We will pay close attention to motivating the enthusiasm of the buyers, purchasers, and middlemen, and to guaranteeing their legal rights. As for profit retention and distribution, we will make clear the relations among the state, groups, and individuals.

3. To promote the further prosperity of the technical markets, we must pay close attention to the restructuring of the three links for scientific and technical achievements that are their development, acceptance, and the intermediaries, based upon the needs of opening up the technology markets and hastening the commercialization of scientific and technical achievements.

One, institutions of higher learning or a research units will gradually change from a pure "planned scientific research model" to a "research operation model." They will securely establish a market concept, an operational concept, and a sense of competition, they will set up and perfect their own operational structures and technology service systems, and they will industriously generate for the technology market technical commodities that are high in quality and for which there is a market. Two, production enterprises will improve enthusiasm for using new technology and will strengthen their economic capacity for purchasing technical achievements. Speaking fundamentally, the prosperity of technology markets will depend upon the demands on technology by production, while the needs of enterprises for technology is also closely related to state policies toward using new technologies and the economic vitality of the enterprises. Therefore, we will politically support and encourage enterprises to use new technology and develop new products, and adopt effective supporting policies through financial channels, pricing, taxation, credit, inspection, and rewards. Enterprises themselves should greatly strengthen their own capacities for technical absorption and development, and relying upon a constant renewal of products from science and technology, should resolve a series of technique and equipment problems regarding quality in industrialized production, consumption of raw materials, and productivity. We will open and guarantee financial channels for technology absorption and development, and will draw up indices based on technology for implementing enterprise economic appreciation. Three, initiate and develop more technology exchange, trade, consulting, service, information, and certification structures of various types, and organize and train technical operations contingents throughout the city to gradually establish and perfect a complete trade system for technology markets. We recommend that the city appoint or create a special organization to be responsible for coordination and unified management of these things and to meet the urgent needs for the rapid development of current technology markets.

4. We will resolutely implement an open-door policy, will connect up domestic technology markets with foreign technology markets, and will consider the absorption, assimilation, innovation on, and transfer of imported advanced technology to be important matters in opening up technology markets that have Guangzhou characteristics. By connecting up imported technology with joint domestic operations, and by joining technical talent and intelligent imports, we can give full play to the function of Guangzhou as a "hinge between two parts of a door."

12586

CSO: 40082032

NATIONAL DEVELOPMENTS

TECHNICAL MARKET THRIVING IN HEBEI

Shijiazhuang HEBEI RIBAO in Chinese 12 Dec 85 p 4

[Article by Shi Pengjun [4258 2590 0689]: "The Technical Market is Thriving in Hebei"]

[Text] The development of the technical market, the commercialization of technology and the acceleration of the entry of technical achievements into the production arena--all this is required by the development of a socialist commodity economy. For over a year now, the Hebei technical market has been flourishing and achieved remarkable results. More than one half of the province's prefectures, counties and municipalities have established permanent technical markets. All localities are launching technical trade activities, besides importing and popularizing a multitude of technical achievements and establishing technical and economic cooperative relations with Beijing, Shanghai and Tianjin in order to promote economic development. At our province's first and second technical achievement trade fairs alone, attended by 20,000 men times, 1,945 technical achievements were traded, worth a total of 36.31 million yuan. Hebei led the nation's provinces, municipalities and autonomous regions in volume of business transacted at the national technical achievement trade fair held in Beijing in May this year.

So far the province has imported and popularized over 4,100 technical achievements through the technical markets, established almost 1,000 scientific research cum production joint organizations with 200 institutions of higher education and research and design units outside the province, and attracted over 4,000 people to Hebei to join us in technical development. We have invented and put into production more than 1,000 new products, many of which have become competitive flagship products. From the simple transfer of technical achievements, the technical market has diversified into an array of services, including the circulation of qualified personnel, bidding for planned scientific research projects, contracting, joint ventures in which one can use technology as capital, joint development between a research unit and a production unit, and the establishment of research-production joint organizations. To increase the purchasing power in the technical market, the financial sector is also getting involved. The provincial science and technology service center, for instance, borrowed 16.25 million yuan this year to support 102 projects extensively.

Over 80 units from Beijing, Shanghai and other places in and outside Hebei will take part in the coming third provincial technical achievement trade fair and talks, bringing with them 1,500 pieces of technical achievements for transfer with compensation. In addition, 1,500 pieces of technical information of various kinds will be announced. The occasion is expected to give a further boost to our technical market.

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CSO: 4008/2048

NATIONAL DEVELOPMENTS

BRIEFS

GUANGDONG TECHNOLOGY IMPORTS--Over the past few years, industrial and communications enterprises in Guangdong Province progressed in importing advanced foreign technology and equipment. From 1982 to the beginning of this year, the province imported 700 items of production and assembly lines and 500,000 sets of equipment. With this technology and equipment, the province has scored marked economic results. Over the past few years, after importing technology, our province has produced approximately 10,000 new varieties. The province's gross industrial output value over the past few years has increased by a yearly average of 9 percent. [Summary] [Guangzhou Guangdong Provincial Service in Mandarin 0400 GMT 28 Jan 86 HK] /12232

TECHNOLOGY IMPORTS--Shenyang, 25 January (XINHUA)--The province of Liaoning, center of China's heavy industry, signed 1,190 contracts for imports of foreign technology worth 860 million U.S. dollars last year, a local official said today. Zheng Silin, who is in charge of this province's foreign economic relations and trade, said last year's imports brought the total number of contracts since 1978 to 2,689 at a total cost of 1.59 billion dollars. Most of the imported technology has been used to renovate more than 1,000 of the province's 16,000 industrial enterprises involving energy, transportation, metallurgy, machinery, electronics, postal and telecommunications, chemicals, building materials, textiles and light industry. In addition, Zheng said, the province's power transmission industry has been modernized to the point where it can export complete equipment systems and undertake construction projects abroad. Imports have also played an important part over the past seven years in developing Liaoning's 12,700 new products, nearly 9,000 of them already in production. The import trade--requiring use of foreign investment--was with more than 20 countries and regions, including Hong Kong, Britain, the Federal Republic of Germany, Italy, Japan, Sweden, and the United States. [Text] [Beijing XINHUA in English 0835 GMT 35 Jan 86 OW] /12913

CSO: 4020/198

IMAGING EQUATION, OPTIMUM ESTIMATION, ALGORITHM OF ULTRASONIC HOLOGRAPHY

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 13 No 3, May 85
pp 71-76

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[Text] Abstract: The imaging equation, optimum estimation model and computer algorithm of ultrasonic Fourier holography are discussed. The effect of background interference and its elimination are analyzed. Good results were obtained using this model and algorithm.

In order to facilitate computer processing of multi-dimensional information, we employed an information estimation and functional analysis method to discuss ultrasonic Fourier holography. This method has advantages such as clear concept and well-defined capabilities. Furthermore, it can facilitate software design. The resulting imaging effect is better than that reported in the literature.[1]

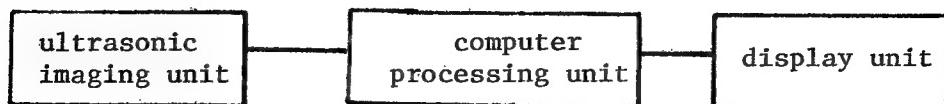
I. Experimental System and Mathematical Imaging Model

The overall three-unit experimental system usually consists of an ultrasonic imaging unit, a computer processing unit and a display unit as shown in Figure 1. In the ultrasonic imaging unit, the emitter produces a series of carrier frequency pulses (e.g. 5 MHz or 1 MHz) at a fixed power toward the emitter transducer. In a certain sense, an emitter transducer with lenses can function as a point source to irradiate a target at a certain distance. An ultrasonic field, i.e. the so-called body function distribution, is established on the target plane as a result of this irradiation. The ultrasonic field distribution on this plane is subsequently recorded by a scanning receiver on a parallel plane, which is called the holographic function distribution. The required complex holographic data can be obtained and recorded on tape by using a dual channel orthogonal demodulator and a microprocessor. There is a well-defined mathematical correlation between the body function and the holographic function, i.e. the imaging equation.

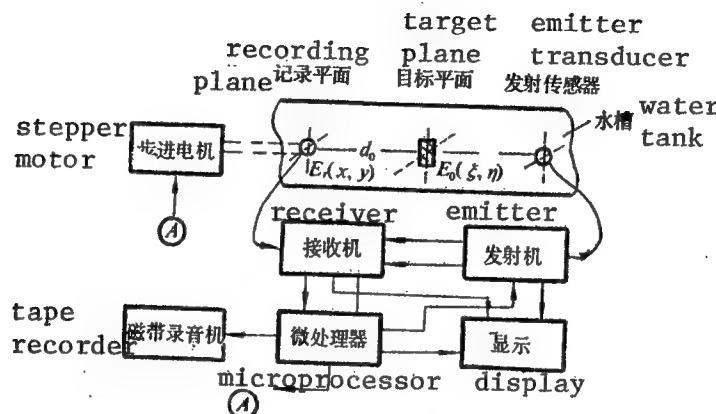
We established the optimum estimation model and algorithm through analysis to process measured holographic data by a computer to obtain a relatively accurate image of the target.

*Received in August 1983, finalized in February 1984.

Figure 1. The Experimental Ultrasonic Holographic System

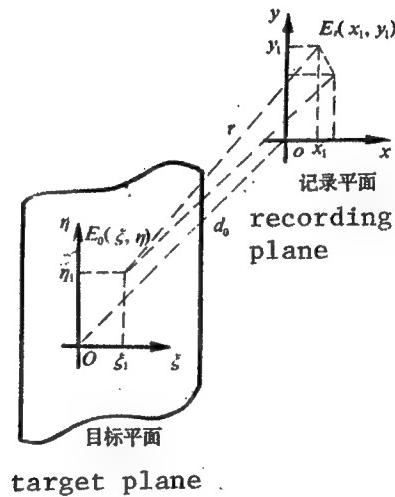


(a) System Scheme



(b) Ultrasonic Imaging Unit

Figure 2. Target Plane and Recording Plane Coordinates



1. Mathematical Description of the Ultrasound Field

The target plane and recording plane coordinates are shown in Figure 2. Let us assume that $E_0(\xi, \eta)$ and $E_r(x, y)$ are ultrasonic station functions in the parallel target and recording coordinates. The ultrasound signal picked up by the receiver at (x, y) is the superposition of all irradiating elements on the target plane. According to the Huygens-Fresnel principle,[2] we get

$$E_r(x, y) = \iint_{(\xi, \eta)} \frac{B}{r} E_0(\xi, \eta) \exp\left[-j2\pi \frac{r}{\lambda}\right] d\xi d\eta \quad (1)$$

where λ is the wavelength of the ultrasound in the medium and B is a proportional constant (independent of r , ξ and η).

In practice, the size of the target and the recording plane are limiting. Moreover, its degree of linearity is far less than that of their separation distance d_0 . Let us assume that they are limited by $(2ax^2b)$ and $(2cx^2d)$ windows, respectively. Based on the Fresnel approximation, the distance r in the exponent term in the above equation can be simplified to:

$$r \approx d_0 + \frac{x^2 + y^2 + \xi^2 + \eta^2}{2d_0} - \frac{x\xi + y\eta}{d_0} \quad (2)$$

The absolute error is less than

$$\max\left(\frac{|x-\xi|^4}{8d_0^4}, \frac{|y-\eta|^4}{8d_0^4}\right)$$

The relative error of the absolute value satisfies the following

$$\epsilon_r < \max\left(\frac{(c+a)^2}{4d_0^2}, \frac{(d+b)^2}{4d_0^2}\right)$$

Here, the mathematical symbol $\max(A, B)$ represents the larger of constants A and B. From equations (1) and (2) we get

$$E_r(x, y) = B_1 \cdot C_d(x, y, d_0) \cdot \iint_{(\xi, \eta)} E_0(\xi, \eta) C_d(\xi, \eta, d_0) \exp\left[-j2\pi \frac{x\xi + y\eta}{\lambda d_0}\right] d\xi d\eta \quad (3)$$

where

$$C_d(x, y, d_0) = \exp\left[-j\frac{\pi}{\lambda d_0}(x^2 + y^2)\right]$$

B_1 is a constant. By introducing a window function

$$W(\xi, \eta, a, b) = \text{rect}(\xi/2a, \eta/2b)$$

where $\text{rect}(\xi, \eta) = \begin{cases} 1, & -1/2 \leq \xi, \eta \leq 1/2 \\ 0, & \text{other} \end{cases}$

then equation (3) can be written as:

$$E_r(x, y) = B_1 W(x, y, a, b) C_d(x, y, d_0) \cdot \iint_{-\infty}^{\infty} E_0(\xi, \eta) W(\xi, \eta, a, b) C_d(\xi, \eta, d_0) \cdot \exp\left[-j2\pi \left(\frac{x}{\lambda d_0}\xi + \frac{y}{\lambda d_0}\eta\right)\right] d\xi d\eta \quad (4)$$

By using the two-dimensional Fourier transformation operator $F[\cdot]$, the above formula can be expressed as:

$$E_r(x, y) = B_1 W(x, y, c, d) C_d(x, y, d_0) \\ \cdot F[E_0(\xi, \eta) W(\xi, \eta, a, b) C_d(\xi, \eta, d_0)] \quad (5)$$

At this point, we can conclude as follows: the measured data $E_r(x, y)$ and the body distribution of the target are roughly a pair of Fourier transforms if the relative error, E_r , is tolerable. The measured data $E_r(x, y)$ is often known as the complex hologram. The relation between the complex holographic function and its corresponding body function is shown in Figure 3. From the figure one can see that a complex holographic function may also be considered as a distorted body function. Hence, equations (4) and (5) not only can be called imaging equations but also distortion equations. Figure 3 is also an imaging or distortion diagram.

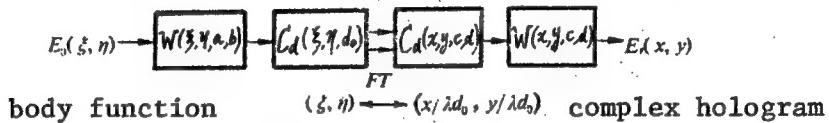


Figure 3. Relation between Body Function and Complex Holographic Function

2. Measured Complex Holographic Data

To obtain the complex holographic data, two channels (as shown in Figure 1(b)) could be used. Equation (5) obtained by using a microprocessor may be in one of the two following cases:

$$E_r(x, y) = \text{Re}[E_r(x, y)] \pm j \text{Im}[E_r(x, y)] \quad (6)$$

In reality, the theoretical analysis of both cases is identical. For simplicity, only the plus sign is used in the following analysis.

3. Effect of Background Interference and Its Elimination

The ultrasound field distribution on the target plane can be considered to include background interference and target field. Therefore, we can establish an additive model

$$E(\xi, \eta) = E_{oi}(\xi, \eta) + E_{bi}(\xi, \eta) \quad (7)$$

Here, $E_{oi}(\xi, \eta)$ is the field distribution of the target and $E_{bi}(\xi, \eta)$ is the field distribution of the background disturbance. They can be expressed as:

$$E_{oi}(\xi, \eta) = \begin{cases} E_0(\xi, \eta), & \text{in target area} \\ 0, & \text{other} \end{cases}$$

and

$$E_{bi}(\xi, \eta) = \begin{cases} 0, & \text{in target area} \\ E_0(\xi, \eta), & \text{other} \end{cases}$$

In ultrasonic holographic imaging, it is satisfactory to use the above additive model to eliminate background interference (as shown in Figure 4).

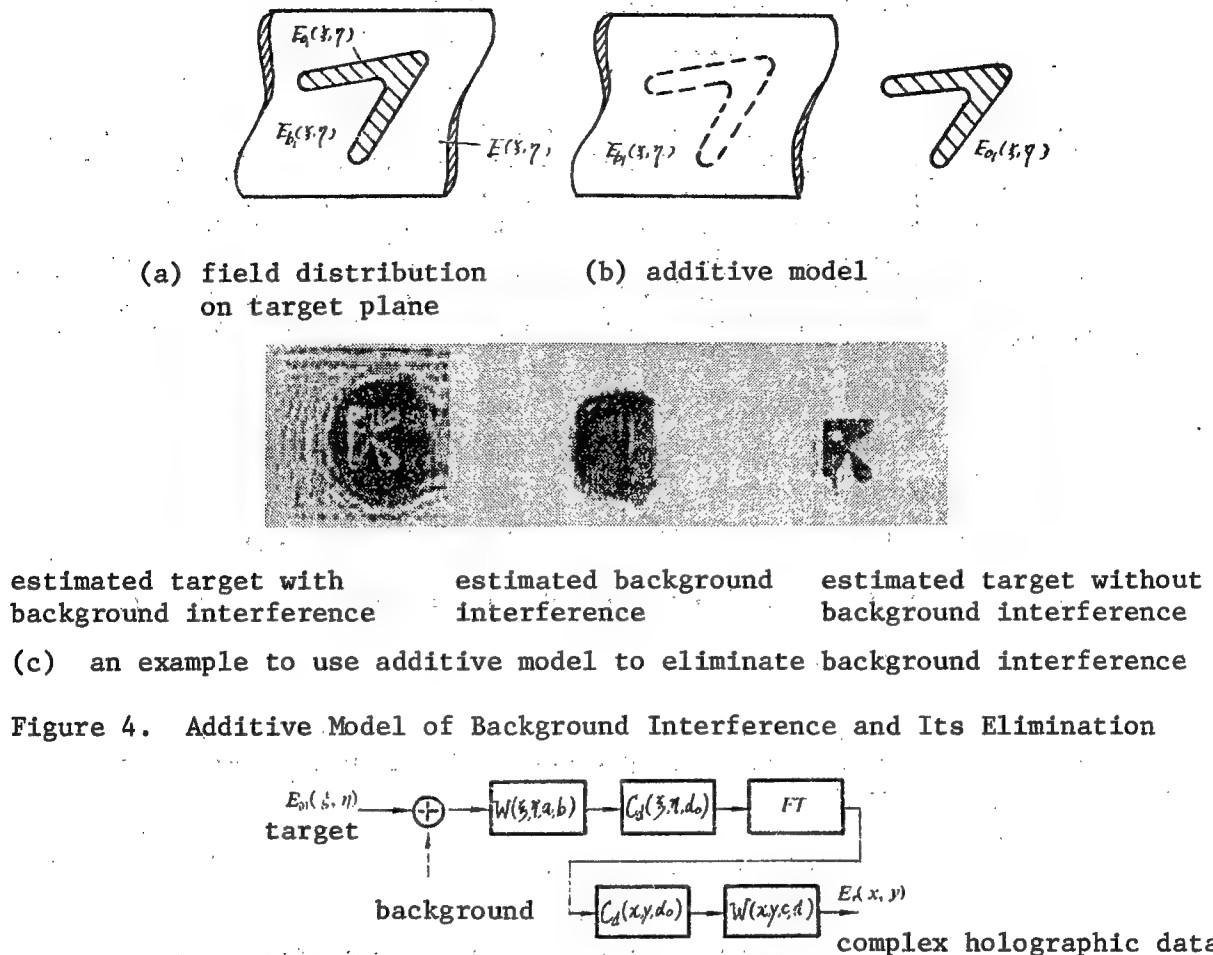


Figure 4. Additive Model of Background Interference and Its Elimination

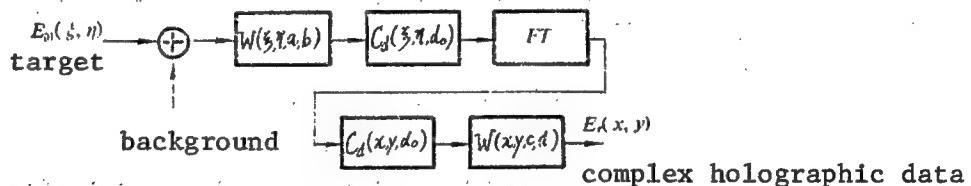


Figure 5. Imaging Function Capable of Eliminating Background Interference

In summary, based on the additive model, the complex holographic imaging expression (5) can be written as:

$$E_t(x,y) = B_1 \cdot W(x,y,c,d) C_d(x,y,d_0) \\ \cdot F[W(\xi,\eta,a,b) C_d(\xi,\eta,d_0) (E_{d1}(\xi,\eta) + E_{b1}(\xi,\eta))] \quad (8)$$

This equation can be verified by Figure 6.

II. The Optimum Image Estimation

1. Mathematical Model for Estimation

When the complex holographic data is given, to estimate or restore a target image is to solve equation (8). If parameters such as the window of the ultrasound system are properly chosen (to be discussed elsewhere), then the

window effect can be neglected. Thus, the optimal estimated image can be expressed as:

$$\hat{E}_{oi}(\xi, \eta) = C_d(\xi, \eta, -d_0) F^{-1}[C_d(x, y, -d_0) \cdot E_r(x, y)] - E_{bi}(\xi, \eta) \quad (9)$$

It should be noted that the spatial frequency variable is $(x/\lambda d_0, y/\lambda d_0)$, in performing an inverse Fourier transform. The background interference can be expressed as:

$$\hat{E}_{bi}(\xi, \eta) = C_d(\xi, \eta, -d_0) F^{-1}[C_d(x, y, -d_0) \cdot E_{rb}(x, y)] \quad (10)$$

In practice it is possible to measure $E_{rb}(\xi, \eta)$, without involving the target when the remaining conditions stay unchanged. Then, $\hat{E}_{bi}(\xi, \eta)$, can be calculated on a computer based on equation (10). The multiplication of the factor function $C_d(\xi, \eta, -d_0)$ in the target estimation equation(9) can be re-written as:

$$\hat{E}_{oi}(\xi, \eta) = \text{Mag}[F^{-1}(C_d(x, y, -d_0)(E_r(x, y) - E_{rb}(x, y))] \quad (11)$$

where the mathematical symbol $\text{Mag}[A] = |A|$.

2. Computerized Processing

The concept of computerized processing of equation (11) is to first sample the original field and then periodically extend the sampled field to obtain a sampled periodic field distribution which is used in the computation. One cycle of this field distribution coincides with the sampling approximation of the original field. This method calculates the effect of FT by using DFT. This important concept is shown in Figure 6. Let the target field and complex hologram to be processed by the computer be $E_{oi,c}(\xi, \eta)$ and $E_{rc}(x, y)$, respectively, then we have the following relation:

$$E_{oi,c}(\xi, \eta) = E_{oi}(\xi + l_{c1}, \eta + m b_1)$$

and

$$E_{rc}(x, y) = E_r(x + l_c, y + m d)$$

where l and m are $0, 1, 2, \dots$. The imaging elements of the target field (i.e. the target picture) a_p and b_p are:

$$a_p = \lambda d_0/c, \quad b_p = \lambda d_0/d$$

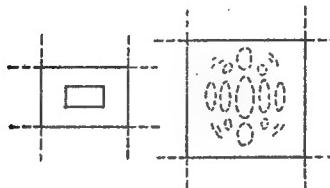
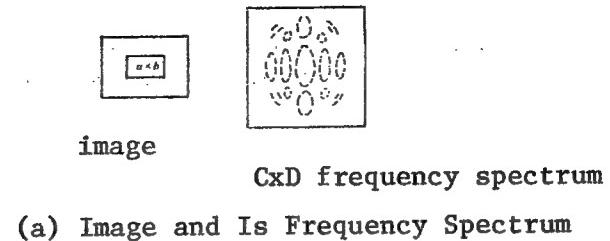
The image size in one basic cycle is:

$$a_1 = \lambda d_0/c, \quad b_1 = \lambda d_0/d$$

It is obvious that the following condition must be satisfied to avoid distortion caused by mingling of neighboring high frequency components.

$$a_1 \geq a, \quad b_1 \geq b$$

In order to obtain a clear picture and to prevent serious high frequency mixing, it is necessary to have a large plane to measure the complex hologram. In approximation, most of the target image spatial frequency components should be concentrated in the spatial frequency range $(c/\lambda d_0, d/\lambda d_0)$ 内。



(b) Computer-generated Image and Frequency Spectrum

Figure 6. Using DFT to Calculate the Effect on FT

Estimation is made according to the following method:

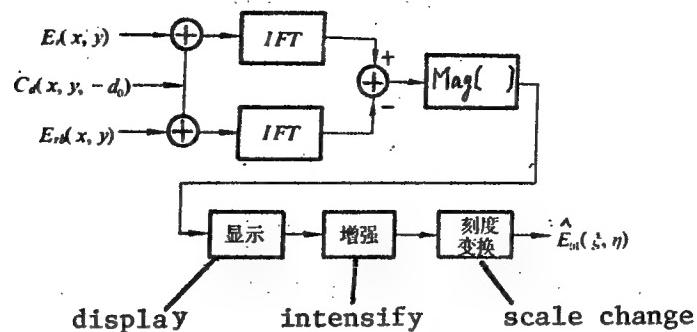
(1) Known Data. $E_r(x, y)$, $E_{rb}(x, y)$ and the following system parameters such as focusing distance d_0 , ultrasound wavelength in the medium λ , sampling space C_p and d_p (usually $C_p=d_p$ and target display dimensions d_{s1} and d_{s2} (usually $d_{s1}=d_{s2}=d_s$) are given.

(2) Algorithm and Procedures. Focus, call function subroutine, $C_d(x, y, -d_0)$, and then do the multiplication $E_r(x, y) \cdot C_d(x, y, -d_0)$ and $E_{rb}(x, y) \cdot C_d(x, y, -d_0)$. Call the DIFT subroutine to calculate $F^{-1}[E_r(x, y) \cdot C_d(x, y, -d_0)]$ and $F^{-1}[E_{rb}(x, y) \cdot C_d(x, y, -d_0)]$. Subtract background interference according to the condition, i.e.

$$F^{-1}[E_r(x, y) \cdot C_d(x, y, -d_0)] - F^{-1}[E_{rb}(x, y) \cdot C_d(x, y, -d_0)];$$

Select amplitude and display (the image estimation equation (11)). Proceed with other image treatments such as image intensifying, pseudo-color transformation and other changes. Determine the actual size of the image through scaling and estimate certain parameters. (The conversion coefficients between the linear display scale and the actual scale are $K_{\xi} = \lambda d_0 / C_p d_s$ and $K_{\eta} = \lambda d_0 / d_p d_s$). Figure 7 shows the block diagram of the estimation method.

Figure 7. Algorithm if Target Estimation by Ultrasonic Holography



III. Experiment

An ultrasonic holographic imaging system was built according to the theory and algorithm discussed above. An aluminum plate, a plastic template and a fish were used as targets to be tested in the experimental pool. In addition to the aluminum plate shown in Figure 4(c), other results are shown in Figures 8-9. Results indicate that estimated images are very close to the real targets and sizes are also very accurate.

It should be pointed out that in addition to theoretical analysis, optimization of a series of parameters in the experiment is also responsible for obtaining clear images shown above. Otherwise, theoretical conditions established above will be destroyed.

Figure 8. Plastic Template (upper)
and Its Estimated Image (lower):

- a. target and background interference
- b. edge intensification
- c. estimated image

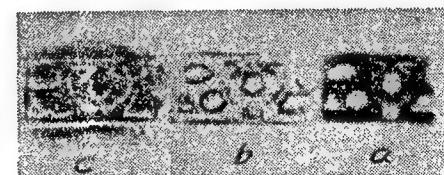
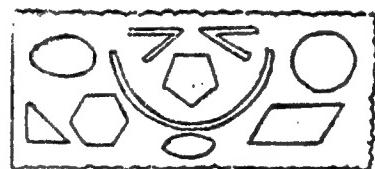
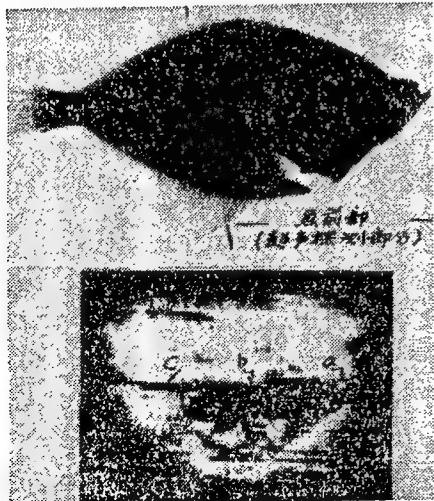


Figure 9. Front Part of a Fish (upper)
and Its Estimated Image (lower)

- a. mouth
- b. gill
- c. spine

Acknowledgement. The authors wish to thank Professor P.A. Matthews of Leeds University in England and Professor A.P. Anderson of Sheffield University in England for their assistance in this study. They also wish to thank Dr. T. Whittka for his assistance in performing the experimental work.

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APPLIED SCIENCE

STATUS OF CHINA'S NUCLEAR S&T RECAPPED

Harbin HEILONGJIANG RIBAO in Chinese 31 Oct 85 p 1

[Article by Zhuo Peirong [0587 1014 2837]]

[Text] Beijing, 30 Oct (XINHUA)--China's nuclear industry has experienced continuous growth since 1955, and its achievements have attracted world attention. A few days ago an official of the Ministry of Nuclear Industry gave a presentation to the reporters outlining the major accomplishments of China's nuclear industry during the past three decades.

--Acquisition of the technologies to develop atomic bombs, hydrogen bombs, and power plants used in nuclear submarines. China has armed its military units with nuclear weapons; the development of nuclear weapons has enhanced China's defensive strength and has been a major factor in protecting the security of this country and maintaining world peace.

--Establishment of a firm foundation in nuclear technology and a comprehensive, nuclear industrial system. This system includes organizations devoted to uranium exploration, mining and processing as well as recycling of nuclear fuel, manufacturing of nuclear weapons, and the peaceful use of nuclear energy and nuclear technology. The development of nuclear science has created many new scientific disciplines, new technologies and new industries such as nuclear medicine, nuclear agriculture and new industries such as nuclear medicine, nuclear agriculture, nuclear environmental protection, nuclear analysis and measurement techniques, nuclear display and tracking techniques, nuclear automatic control technology, nuclear radiation processing industry, and nuclear electronic instrument manufacturing industry; a number of these technologies have already been successfully implemented in various applications.

--Development of China's uranium resources and establishment of technical service facilities for uranium products and other related products. China has already accumulated a sizable reserve of atomic fuel for nuclear power plants and a reserve of uranium products. The instrument manufacturing capability, engineering design capability and construction/installation capability of the nuclear industry have been extensively used in non-nuclear applications.

--Establishment of a firm foundation in nuclear power generation. Currently China has 10 nuclear reactors of various types, and has accumulated

considerable operational experience. The Chinshan nuclear power plant project in Zhejiang Province is making good progress, and efforts have been initiated in the theoretical resource of nuclear power plants for heat generation.

--Training a team of highly qualified technical personnel for the nuclear industry.

This official said that China's nuclear industry is following the current trend both in this country and abroad to redirect its energy for economic construction. In recent years, the demands of China's economic and social development have supplied constant challenges to the nuclear industry. With increasing public awareness about nuclear technology, it will undoubtedly play an increasing role in the lives of the Chinese people.

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APPLIED SCIENCES

COUPLING PROPERTIES OF SLOTTED ANTENNA STUDIED

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 13 No 5,
Sep 85 pp 92-101

[Article by Lu Shanwei [0712 0810 0251], Ren Jishi [0117 3444 2514], and Fang Yin [2455 1944], Beijing Institute of Aeronautics and Astronautics; "Study of Coupling Properties of Slotted Antenna in a Rectangular Waveguide"]

[Text] Text of English Abstract: Coupling properties of any two longitudinal slots in the wider walls of a rectangular waveguide are analyzed. The theoretical results are in good agreement with the experimental results and with the data previously obtained (for single slot and half-wavelength slots). Based on the calculated and the experimental results, the electric field distribution at the aperture surface, the admittance, the resonant conductance, and the resonant length of the slots are discussed, taking into account both the effects of external and internal mutual coupling between the slots. The effects of the waveguide wall thickness and narrow-side width are also discussed.

I. Introduction

There are great difficulties in calculating quantitatively the mutual coupling effect between slots in a slotted antenna array, thus design of slotted arrays in the 1950's and 1960's was basically based on isolated slot impedance theory[1-3]. Document [4] analyzed the coupling characteristics of two longitudinal half-wave slots on the wide-side of the waveguide but did not give engineering equations of the coupling characteristics of half waveguide wave length slots of the customary distance for situations in which the slot length is fixed and the wall thickness is zero. Documents [5,6, and 7] used the moments method to begin analyzing the characteristics of single slots by solving the problem of electromagnetic field boundary values and obtained a solution with a certain precision. On the basis of the duality principle, documents [8 and 9] used a known vibrator mutual coupling system to compute the mutual coupling of a slot on the outside of the waveguide, and although they obtained excellent experimental results, they still did not take into consideration the mutual coupling effect on the inside of the waveguide. Recent articles[10,11] are similar. By proceeding from constructing a strict mathematical model and solving the problem of boundary values, this paper attempts, on the foundation work of earlier people, to use the Galerkin's

method to analyze the coupling characteristics of two slots on the waveguide wide-side having a definite thickness, any position and the same and different dimensions. The paper deduces theoretically two slots of different dimensions, and at the time of numerical computation and experimentation, selected a typical situation of identical dimensions and the results are still universal. Separately taking and not taking into account mutual coupling, we computed the slot aperture field distribution, scattering parameters, and the relationship of equivalent admittance and slot length, shift, waveguide dimensions and wall thickness and frequency. The theoretical calculations and experimental results are rather uniform.

II. Theory

1. Setting Up Integral Equations

The slotted antenna structure and its coordinate system are illustrated in Figure 1. Hypotheses: (1) the waveguide extends along the z axis towards positive and negative infinity; (2) the thickness of the waveguide walls is the ideal semiconductor of T, the slots are located on an indefinitely large conducting surface; (3) the narrow slot's length/width > 10 ; (4) the slot is excited by an H_{10} wave from the negative z direction and only H_{10} waves are transmitted in the waveguide.

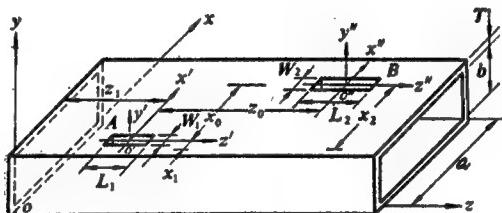


Figure 1. Diagram of slot structure and coordinates

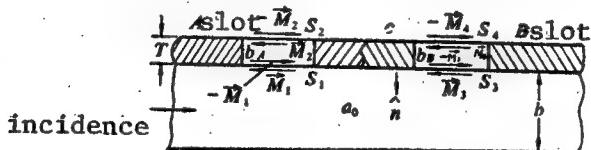


Figure 2. Diagram of partitioned and equivalent magnetic flow

a_0 is the inner region of the waveguide; b_A is the A region of the cavity; b_B is the B region of the cavity; c is the half-space region; $M_k = E_k x \hat{n}$, $k=1,2,3,4$; S_k is the slot aperture at M_k .

From the principle of equivalency, we can use an ideal conducting plate to divide the slotted antenna structure in Figure 1 into four regions: waveguide, cavities A and B, and half-space, as illustrated in Figure 2.

From the continuity of the tangential component of the magnetic field at the slot apertures we can obtain the following integral equation groups:

$$\frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \left\{ \iint_{S_1} (-M_1) [G_a^{zz}(r, r') + G_{bA}^{zz}(r, r')] dS'_1 \right. \\ \left. + \iint_{S_2} M_2 G_{bA}^{zz}(r, r') dS'_2 + \iint_{S_3} (-M_3) G_a^{zz}(r, r') dS'_3 + 0 \right\} = H_{iA} \quad (r \text{ on } S_1 \text{ surface}) \quad (1)$$

$$\frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \left\{ \iint_{S_1} M_1 G_{bA}^{zz}(r, r') dS'_1 + \iint_{S_2} (-M_2) [G_{bB}^{zz}(r, r') + G_c^{zz}(r, r')] dS'_2 \right. \\ \left. + 0 + \iint_{S_4} (-M_4) G_c^{zz}(r, r') dS'_4 \right\} = 0 \quad (r \text{ on } S_2 \text{ surface}) \quad (2)$$

$$\frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \left\{ \iint_{S_1} (-M_1) G_a^{zz}(r, r') dS'_1 + 0 + \iint_{S_3} (-M_3) [G_a^{zz}(r, r') + G_{bB}^{zz}(r, r')] dS'_3 \right. \\ \left. + \iint_{S_4} M_4 G_{bB}^{zz}(r, r') dS'_4 \right\} = H_{iB} \quad (r \text{ on } S_3 \text{ surface}) \quad (3)$$

$$\frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \left\{ 0 + \iint_{S_2} (-M_2) G_c^{zz}(r, r') dS'_2 + \iint_{S_3} M_3 G_{bB}^{zz}(r, r') dS'_3 \right. \\ \left. + \iint_{S_4} (-M_4) [G_{bB}^{zz}(r, r') + G_c^{zz}(r, r')] dS'_4 \right\} = 0 \quad (r \text{ on } S_4 \text{ surface}) \quad (4)$$

in which: G_a^{zz} is the $\hat{z}\hat{z}$ component of the dyad potential Green function \bar{G}_a of the waveguide; G_b^{zz} is the $\hat{z}\hat{z}$ component of the dyad potential Green function \bar{G}_b of the cavity; G_c^{zz} is the $\hat{z}\hat{z}$ component of the dyad potential Green function \bar{G}_c of the half-space; r' is at each magnetic flow source; $k^2 = \omega^2 \epsilon \mu$

The wave motion equation which the Green function of each region satisfies and the boundary conditions which satisfy on the metallic surface are respectively:

$$\nabla^2 \bar{G}(r, r') + k^2 \bar{G}(r, r') = -\bar{I} \delta(r, r') \quad (5)$$

$$\hat{n} \times \nabla \times \bar{G}(r, r') = 0, \quad \hat{n} \cdot \bar{G}(r, r') = 0 \quad (6)$$

in which \bar{I} is the unit dyad, δ is the delta function. We can derive:

$$G_a^{zz}(r, r') = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{\epsilon_{om}\epsilon_{on}}{2jabU_{mn}} \cos \frac{m\pi x'}{a} \cos \frac{m\pi x}{a} \cos \frac{n\pi y'}{b} \cos \frac{n\pi y}{b} e^{-jU_{mn}|z-z'|} \quad (7)$$

in which

$$U_{mn} = \begin{cases} \sqrt{k^2 - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{b}\right)^2}, & k^2 \geq \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 \\ -j\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - k^2}, & k^2 < \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 \end{cases} \quad (8)$$

$$\begin{aligned} G_b^{zz}(r, r') = & - \sum_{l=0}^{\infty} \sum_{m=1}^{\infty} \sum_{n=0}^{\infty} \frac{2\epsilon_{ol}\epsilon_{on}}{WLT \left[k^2 - \left(\frac{\pi l}{W}\right)^2 - \left(\frac{m\pi}{L}\right)^2 - \left(\frac{n\pi}{T}\right)^2 \right]} \\ & \cdot \frac{l\pi\left(x' + \frac{W}{2}\right)}{W} \cos \frac{l\pi\left(x + \frac{W}{2}\right)}{W} \sin \frac{m\pi\left(z' + \frac{L}{2}\right)}{L} \sin \frac{m\pi\left(z + \frac{L}{2}\right)}{L} \\ & \cdot \cos \frac{n\pi\left(y' + \frac{T}{2}\right)}{T} \cos \frac{n\pi\left(y + \frac{T}{2}\right)}{T} \end{aligned} \quad (9)$$

the point of origin of the coordinates is located at the center of the cavity;
in Eqs. (7) and (9)

$$\epsilon_{ol, m, n} = \begin{cases} 1, & l, m, n = 0 \\ 2, & l, m, n \neq 0 \end{cases} \quad (10)$$

$$G_c^{zz}(r, r') = \exp[-jk|r-r'|]/2\pi|r-r'| \quad (11)$$

2. Deriving the Integral Equations

For convenience, we introduced the following operators:

$$\left. \begin{aligned} L_{11} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_1} -[G_a^{zz}(r, r') + G_{bA}^{zz}(r, r')] dS'_1 \\ L_{12} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_2} G_{bA}^{zz}(r, r') dS'_2 \\ L_{13} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_3} -G_a^{zz}(r, r') dS'_3 \\ L_{14} &= 0 \end{aligned} \right\} \quad \text{r on surface } S_1 \quad (12)$$

$$\left. \begin{aligned} L_{21} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_1} G_{bA}^{zz}(r, r') dS'_1 \\ L_{22} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_2} -[G_{bA}^{zz}(r, r') + G_c^{zz}(r, r')] dS'_2 \\ L_{23} &= 0 \\ L_{24} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_4} -G_c^{zz}(r, r') dS'_4 \end{aligned} \right\} \quad \text{r on surface } S_2 \quad (13)$$

$$\left. \begin{aligned} L_{31} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_1} -G_a^{zz}(r, r') dS'_1 \\ L_{32} &= 0 \\ L_{33} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_3} -[G_a^{zz}(r, r') + G_{bB}^{zz}(r, r')] dS'_3 \\ L_{34} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_4} G_{bB}^{zz}(r, r') dS'_4 \\ L_{41} &= 0 \end{aligned} \right\} \quad \text{r on surface } S_3 \quad (14)$$

$$\left. \begin{aligned} L_{42} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_2} -G_c^{zz}(r, r') dS'_2 \\ L_{43} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_3} G_{bB}^{zz}(r, r') dS'_3 \\ L_{44} &= \frac{1}{j\omega\mu} \left(k^2 + \frac{d^2}{dz^2} \right) \iint_{S_4} -[G_{bB}^{zz}(r, r') + G_c^{zz}(r, r')] dS'_4 \end{aligned} \right\} \quad \text{r on surface } S_4 \quad (15)$$

then Eqs. (1-4) can be written:

$$L_{11}M_1 + L_{12}M_2 + L_{13}M_3 + L_{14}M_4 = H_{1A}(r), \quad (r \text{ on surface } S_1) \quad (16)$$

$$L_{21}M_1 + L_{22}M_2 + L_{23}M_3 + L_{24}M_4 = 0, \quad (r \text{ on surface } S_2) \quad (17)$$

$$L_{31}M_1 + L_{32}M_2 + L_{33}M_3 + L_{34}M_4 = H_{1B}(r), \quad (r \text{ on surface } S_3) \quad (18)$$

$$L_{41}M_1 + L_{42}M_2 + L_{43}M_3 + L_{44}M_4 = 0, \quad (r \text{ on surface } S_4) \quad (19)$$

the boundary conditions which satisfy M_k , $k=1,2,3,4$ is

$$M_1|_{z'=\pm L_{1/2}} = M_2|_{z'=\pm L_{1/2}} = M_3|_{z'=\pm L_{3/2}} = M_4|_{z'=\pm L_{3/2}} = 0 \quad (20)$$

Eqs. (16)-(19) combine with boundary condition Eq. (20) for form the dingjie [1353 6043] problem of M_k .

We supposed $f_s^{(k)}$ ($s=1,2,\dots,\infty$) is a complete normal function system within the definition of operator L_{kk} , M_k can be approximated by N linearly unrelated $f_s^{(k)}$ linear groups:

$$M_k = \sum_{s=1}^N a_s^{(k)} f_s^{(k)}(r), \quad r' \in S_k \quad (21)$$

In addition, we took a complete function system $f_i^{(k)}(r)$ ($i=1,2,\dots,\infty$), $r \in S_k$, termed a weight function and defined the inner product as:

$$\langle f_i, f_s \rangle_{S_k} = \iint_{S_k} f_i f_s dS_k \quad (22)$$

Substituting Eq. (21) in Eqs. (16)-(19), multiplying both sides of the equality by $f_i^{(k)}$ ($i=1,2,\dots,N$) and taking the inner product defined by Eq. (22), then Eqs. (16)-(19) can be changed into matrix equations of the following form:

$$\begin{bmatrix} [A] & [B] & [C] & [D] \\ [E] & [F] & [G] & [H] \\ [K] & [L] & [M] & [N] \\ [O] & [P] & [Q] & [R] \end{bmatrix} \begin{bmatrix} [a^{(1)}] \\ [a^{(2)}] \\ [a^{(3)}] \\ [a^{(4)}] \end{bmatrix} = \begin{bmatrix} [h^4] \\ [0] \\ [h^8] \\ [0] \end{bmatrix} \quad (23)$$

The square matrix on the left in the above equation is a $4N \times 4N$ order matrix, in which $[A] - [R]$ are $N \times N$ order sub-matrices, called the admittance matrix; $[h^A]$ and $[h^B]$ are N order column subarrays, called the current matrix. $[C]$ and $[K]$ sub-matrices represent the inner mutual coupling, $[H]$ and $[P]$ represent outer mutual coupling. The elements in the admittance and current matrices are, respectively:

$$\begin{aligned}
A_{i,s} &= \langle L_{11}f_i^{(1)}, f_i^{(1)} \rangle_{s1}, & B_{i,s} &= \langle L_{12}f_i^{(2)}, f_i^{(1)} \rangle_{s1} \\
C_{i,s} &= \langle L_{13}f_i^{(3)}, f_i^{(1)} \rangle_{s1}, & D_{i,s} &= 0 \\
E_{i,s} &= \langle L_{14}f_i^{(4)}, f_i^{(1)} \rangle_{s1}, & F_{i,s} &= \langle L_{21}f_i^{(2)}, f_i^{(2)} \rangle_{s2} \\
G_{i,s} &= 0, & H_{i,s} &= \langle L_{24}f_i^{(4)}, f_i^{(2)} \rangle_{s2} \\
K_{i,s} &= \langle L_{31}f_i^{(1)}, f_i^{(3)} \rangle_{s3}, & L_{i,s} &= 0 \\
M_{i,s} &= \langle L_{33}f_i^{(3)}, f_i^{(3)} \rangle_{s3}, & N_{i,s} &= \langle L_{34}f_i^{(4)}, f_i^{(3)} \rangle_{s3} \\
O_{i,s} &= 0, & P_{i,s} &= \langle L_{42}f_i^{(2)}, f_i^{(4)} \rangle_{s4} \\
Q_{i,s} &= \langle L_{43}f_i^{(3)}, f_i^{(4)} \rangle_{s4}, & R_{i,s} &= \langle L_{44}f_i^{(4)}, f_i^{(4)} \rangle_{s4} \\
h_i^A &= \langle H_{iA}, f_i^{(1)} \rangle_{s1}, & h_i^B &= \langle H_{iB}, f_i^{(3)} \rangle_{s3}
\end{aligned} \tag{24}$$

By the reciprocity theorem it is easy to prove:

$$B_{i,s} = E_{i,s}, \quad C_{i,s} = K_{i,s}, \quad H_{i,s} = P_{i,s}, \quad N_{i,s} = Q_{i,s} \tag{25}$$

$[a^{(1)}] - [a^{(4)}]$ is the voltage coefficient matrix which is to be found. Select the appropriate N [13] on the basis of the precision required and after finding the matrix elements using Eq. (24), the coefficient $a_s^{(k)}$ can be found by inversion using Eq. (23). Thus the problem comes down to finding the inner product showed in Eq. (24).

Processing the inner product is complex and time consuming, and because it would take too long, here we give the results after detailed derivation.

Using the Galer Kin's method, we take the base and weight function of each aperture as:

$$f_i^{(1)} = f_i^{(2)} = \sin \frac{s\pi(\eta' + L_1/2)}{L_1}, \quad -\frac{L_1}{2} \leq \eta' \leq \frac{L_1}{2} \tag{26}$$

$$f_i^{(3)} = f_i^{(4)} = \sin \frac{s\pi(\eta'' + L_2/2)}{L_2}, \quad -\frac{L_2}{2} \leq \eta'' \leq \frac{L_2}{2} \tag{27}$$

$$f_i^{(1)} = f_i^{(2)} = \sin \frac{i\pi(z' + L_1/2)}{L_1}, \quad -\frac{L_1}{2} \leq z' \leq \frac{L_1}{2} \tag{28}$$

$$f_i^{(3)} = f_i^{(4)} = \sin \frac{i\pi(z'' + L_2/2)}{L_2}, \quad -\frac{L_2}{2} \leq z'' \leq \frac{L_2}{2} \tag{29}$$

Below we give the results of the inner products of each region in sequence, i.e., the specific expression for each element in the admittance matrix.

(1) inner products of the admittance region A_{isa} , M_{isa} , and C_{is} , respectively are:

$$\begin{aligned}
 A_{isa} &= \langle L_{11} f_i^{(1)}, f_i^{(1)} \rangle_{s_1} \\
 &= \frac{W_1^2}{2ab\omega\mu} \sum_{m=0}^{\infty} e_{om} \left[\frac{\sin(\alpha W_1/2)}{\alpha W_1/2} \cos \alpha x_1 \right]^2 \left\{ [\delta_{mo} - (k^2 - s^2 \xi^2) \gamma(m)] \right. \\
 &\quad \cdot j L_1 \delta_{is} + \sum_{n=0}^{\infty} e_{on} \frac{2s_i \xi^2}{U_{mn} [s^2 \xi^2 - U_{mn}^2]} \frac{\alpha^2 - \beta^2}{i^2 \xi^2 - U_{mn}^2} \\
 &\quad \cdot [1 - (-1)^i e^{-j U_{mn} L_1}] \Big\}, \quad i+s = \text{even} \\
 &\quad 0, \quad i+s = \text{odd}
 \end{aligned} \tag{30}$$

in which: $\alpha = m\pi/a$, $\beta = n\pi/b$, $\xi = \pi/L_1$, $n \neq m = 0$

$$\delta_{is} = \begin{cases} 1, & i=s \\ 0, & i \neq s \end{cases}, \quad \delta_{mo} = \begin{cases} 1, & m=0 \\ 0, & m \neq 0 \end{cases} \tag{31}$$

$$\gamma(m) = \frac{b}{\sqrt{k^2 - s^2 \xi^2 - \alpha^2}} \cot b \sqrt{k^2 - s^2 \xi^2 - \alpha^2} \tag{32}$$

$$C_{is} = \langle L_{13} f_i^{(3)}, f_i^{(1)} \rangle_{s_1} = \frac{W_1 W_2}{2ab\omega\mu} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{e_{om} e_{on}}{U_{mn}}$$

$$\cdot \frac{\sin(\alpha W_1/2)}{\alpha W_1/2} \frac{\sin(\alpha W_2/2)}{\alpha W_2/2} \cos \alpha x_1 \cos \alpha x_2 \cdot \begin{cases} \Xi_1 \\ \Xi_2 \end{cases} \tag{33}$$

$$\begin{aligned}
 \text{in which: } \Xi_1 &= (\alpha^2 + \beta^2) \frac{\zeta}{\zeta^2 - U_{mn}^2} \frac{i\xi}{i^2 \xi^2 - U_{mn}^2} e^{-j U_{mn} z_0} [e^{j U_{mn} L_2/2} - (-1)^i e^{-j U_{mn} L_2/2}] \\
 &\quad \cdot [e^{-j U_{mn} L_1/2} - (-1)^i e^{j U_{mn} L_1/2}], \quad (L_1/2) + (L_2/2) \leq z_0
 \end{aligned}$$

$$\Xi_2 = (\alpha^2 + \beta^2) \frac{\zeta}{\zeta^2 - U_{mn}^2} \frac{i\xi}{i^2 \xi^2 - U_{mn}^2} [e^{-j U_{mn}(z_0 - L_2/2 + L_1/2)} - (-1)^i e^{-j U_{mn}(z_0 + L_2/2 + L_1/2)} \tag{33a}$$

$$+ (-1)^{i+s} e^{-j U_{mn}(z_0 + L_2/2 + L_1/2)} - (-1)^i e^{j U_{mn}(z_0 - L_2/2 - L_1/2)}] + j U_{mn} \cdot \begin{cases} A_1 \\ A_2 \end{cases} \tag{33b}$$

in which: $\zeta = s\pi/L_2$; $A_1 = \frac{1}{\zeta^2 - U_{mn}^2}$, $\frac{1}{i^2\xi^2 - U_{mn}^2}$, $\frac{1}{\zeta^2 - i^2\xi^2} \left\{ 2\zeta [k^2 - i^2\xi^2] \sin \left[\left(\frac{z_0 - L_2/2}{L_1/2} + 1 \right) \frac{i\pi}{2} \right] [\zeta^2 - U_{mn}^2] - (-1)^{i+s} 2i\xi [k^2 - \zeta^2] \sin \left[\left(\frac{z_0 - L_2/2}{L_2/2} + 1 \right) \frac{s\pi}{2} \right] [i^2\xi^2 - U_{mn}^2] \right\}$, $i \neq s$,

$$L_1 \neq L_2; A_2 = \left\{ \frac{2s\pi/2}{(\zeta^2 - U_{mn}^2)^2} (\alpha^2 + \beta^2) \sin \left(\frac{z_0 - L_2/2}{L_2/2} - \frac{i\pi}{2} \right) + \frac{k^2 - \zeta^2}{\zeta^2 - U_{mn}^2} [(L_2 - z_0) \cos \zeta z_0 + \frac{1}{\zeta} \sin \zeta z_0] \right\}, \quad i = s, \quad L_1 = L_2, \quad (L_1 + L_2)/2 > z_0$$

$$M_{iss} = A_{iss} |_{L_1=L_2, W_1=W_2, x_1=x_2} \quad (34)$$

(2) Inner products of the cavity region A_{isbA} , B_{isbA} , F_{isbA} , M_{isbA} , R_{isbB} respectively are:

$$A_{isbA} = \langle L_B f_i^{(1)}, f_i^{(1)} \rangle_{ss} = \frac{1}{j\omega u} \frac{W_1 L_1}{2} \frac{a'_A \cos a'_A T}{\sin a'_A T} \delta_{is} \quad (35)$$

$$B_{is} = \frac{-1}{j\omega u} \frac{W_1 L_1}{2} \frac{a'_A}{\sin a'_A T} \delta_{is}, \quad F_{isbA} = A_{isbA} \quad (36)$$

$$M_{iss} = R_{iss} = A_{iss} |_{L_1=L_2, W_1=W_2, a'_A = a'_B}, \quad N_{is} = B_{is} |_{L_1=L_2, W_1=W_2, a'_A = a'_B}$$

in which: $a'_A = \sqrt{k^2 - s^2\xi^2}$; $a'_B = a'_A |_{L_1=L_2}$; $\delta_{is} = 1(i=s), = 0(i \neq s)$

(3) Inner products of the half-space region H_{is} , F_{isc} , R_{isc} respectively are:

$$H_{is} = \langle L_B f_i^{(4)}, f_i^{(2)} \rangle_{ss} \quad (37)$$

$$= \frac{1}{j\omega u 16\pi} \left\{ \int_{-\sigma}^{\sigma} A_p \sin \left[\frac{i\pi}{2} \left(\frac{2v}{L_1} - 1 + \frac{L_2}{L_1} \right) \right] [(-1)^{i+s} f_2(v) + f_2(-v)] dv \right. \\ \left. + \int_{-\sigma}^{-\sigma} B_p \sin \left[\frac{s\pi}{2} \left(\frac{2v}{L_2} - 1 + \frac{L_1}{L_2} \right) \right] [(-1)^{i+s} f_2(-v) + f_2(v)] dv \right\}, \quad \begin{matrix} L_1 \neq L_2 \\ W_1 \neq W_2 \end{matrix}$$

in which: $\sigma = (L_1 - L_2)/2$; $v = -(L_1 + L_2)/2$; $A_p = \frac{2k^2}{\pi \mathcal{L}_+} - \frac{2k^2}{\pi \mathcal{L}_-} - \frac{i\pi \mathcal{L}_-}{L_1 \mathcal{L}_+} + \frac{i\pi \mathcal{L}_+}{L_1 \mathcal{L}_-}$; B_p

$$= \frac{2k^2}{\pi \mathcal{L}_+} + \frac{2k^2}{\pi \mathcal{L}_-} + \frac{i\pi \mathcal{L}_-}{L_2 \mathcal{L}_+} + \frac{i\pi \mathcal{L}_+}{L_2 \mathcal{L}_-}; f_2(v) = \iint_{D'} \frac{\exp[-jk\sqrt{(u'-x_0)^2 + (v-z_0)^2}]}{(u'-x_0)^2 - (v-z_0)^2} du' dv;$$

in which:

$$\mathcal{L}_+ = (i/L_1) + (s/L_2), \quad \mathcal{L}_- = (i/L_1) - (s/L_2),$$

integral region D' is a sloped rectangular region with the four points--A₀ [(W₁-W₂)/2, (W₁+W₂)/2], B₀[-(W₁+W₂)/2, (W₂-W₁)/2], C₀[(W₂-W₁)/2, -(W₁+W₂)/2], D₀[(W₁+W₂)/2, (W₁-W₂)/2]. If W₂=W₁=W, L₁=L₂=L, then

$$f(v) = f_2(v) = 2 \int_0^W (-u+W) \left(\frac{e^{-ikr_1}}{r_1} + \frac{e^{-ikr_2}}{r_2} \right) du$$

$$\text{in which: } r_1 = \sqrt{(u+x_0)^2 + (v-z_0)^2}, \quad r_2 = \sqrt{(u-x_0)^2 + (v-z_0)^2}$$

$$F_{i,s,c} = \begin{cases} \frac{1}{j\omega\mu\pi} \left[\int_0^{L_1} \frac{2L_1}{\pi(i^2-s^2)} \{s[k^2-i^2\xi^2]\sin i\xi v - i[k^2-s^2\xi^2]\sin s\xi v\} g(v) dv, & i+s=\text{even}, i \neq s \\ 0, & i+s=\text{odd}, i \neq s \end{cases} \quad (38)$$

$$\text{in which: } g(v) = -j \int_0^{W_1} (-u+W_1) \frac{\sin k\sqrt{u^2+v^2}}{\sqrt{u^2+v^2}} du + \frac{1}{k} (\sin kv - \sin k) \sqrt{W_1^2+v^2}$$

$$+ W_1 \left[\ln \frac{W_1 + \sqrt{W_1^2+v^2}}{v} - \int_0^{W_1} \frac{1-\cos k\sqrt{u^2+v^2}}{\sqrt{u^2+v^2}} du \right]$$

$$R_{i,s,c} = F_{i,s,c} \Big|_{L_1=L_2, W_1=W_2} \quad (39)$$

Finally we can write the other admittance matrix elements:

$$\begin{aligned} A_{i,s} &= A_{i,s,a} + A_{i,s,bA}, & F_{i,s} &= F_{i,s,c} + F_{i,s,bA} (= A_{i,s,bA}) \\ M_{i,s} &= M_{i,s,B} (= R_{i,s,bB}) + M_{i,s,a}, & R_{i,s} &= R_{i,s,c} + R_{i,s,bB} (= M_{i,s,bB}) \end{aligned} \quad \} \quad (40)$$

(4) Inner production of excitation h^A and h^B. Supposing the incident H₁₀ wave longitudinal magnetic field component H₁=A₀cos(πx/a)·e^{-jU₁₀z} (in numerical calculations A₀=1), then we have

$$h_i^A = \langle H_{i,A}, f_i^{(1)} \rangle_{s_1}$$

$$= \begin{cases} 2A_0W_1 \cos \frac{\pi x_1}{a} \frac{i\xi}{i^2\xi^2 - U_{10}^2} \cos \left(\frac{L_1}{2} U_{10} \right), & i=\text{odd} \\ j2A_0W_1 \cos \frac{\pi x_1}{a} \frac{i\xi}{i^2\xi^2 - U_{10}^2} \sin \left(\frac{L_1}{2} U_{10} \right), & i=\text{even} \end{cases} \quad (53)$$

$$h_i^B = \langle H_{i,B}, f_i^{(3)} \rangle_{s_3} = h_i^A e^{-jU_{10}x_0} \Big|_{L_1=L_2, W_1=W_2, x_1=x_3} \quad (54)$$

$a_s^{(1)}$ and $a_s^{(3)}$ found through the matrix inversely, M_1 and M_2 are known, then their scattering field inside the waveguide can be found and the discontinuities caused by the slots can be described using the equivalent network. Let only H_{10} waves be transmitted in the waveguide, the two reference surfaces selected are in the center of A and B slots, and the observation point is sufficiently far from this foot. Thus from the scattering field we can find the equivalent scattering parameter S , and from the relationship of S and the equivalent admittance Y , find Y , through a certain approximation, Y_A or Y_B can be found[15].

III. Theoretical Calculations and Experimental Results

On the x wave band, specific calculations and experimental research was carried out on two longitudinal slots of equal length spaced $\lambda_g/2$ apart on the same waveguide.

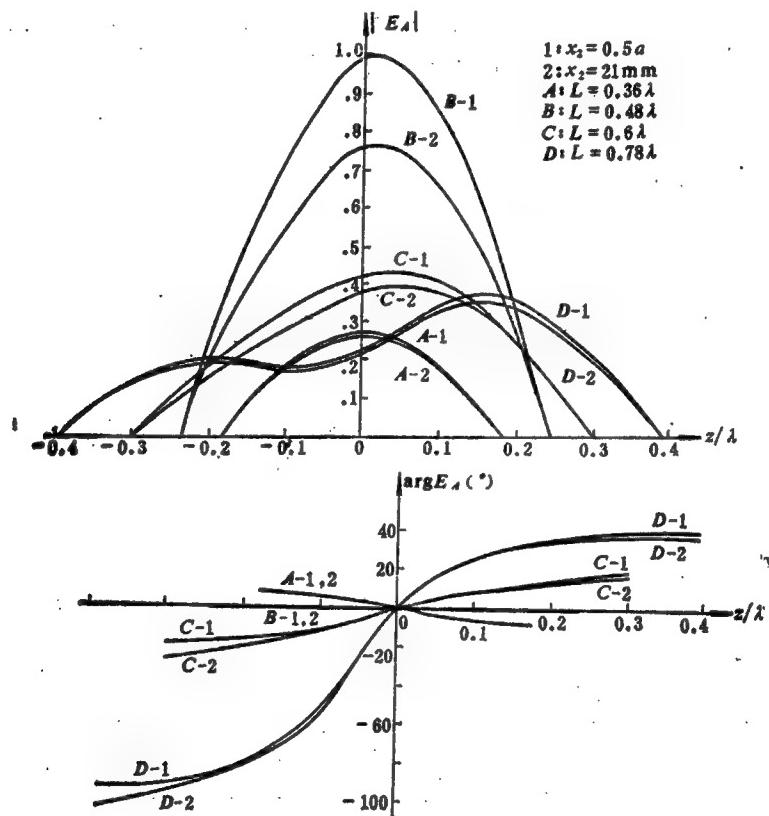


Figure 3. Electrical field distribution tangential to slot A aperture

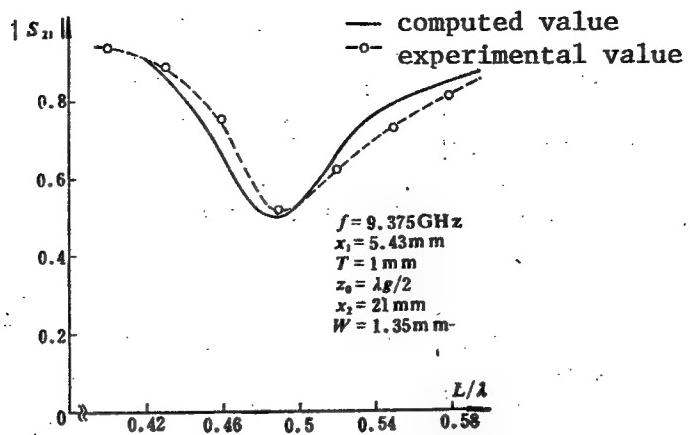


Figure 4. Curve of the relationship of twin slot transmission coefficient $|S_{21}|$ and slot length L ($|S_{21}|=|S_{12}|$)

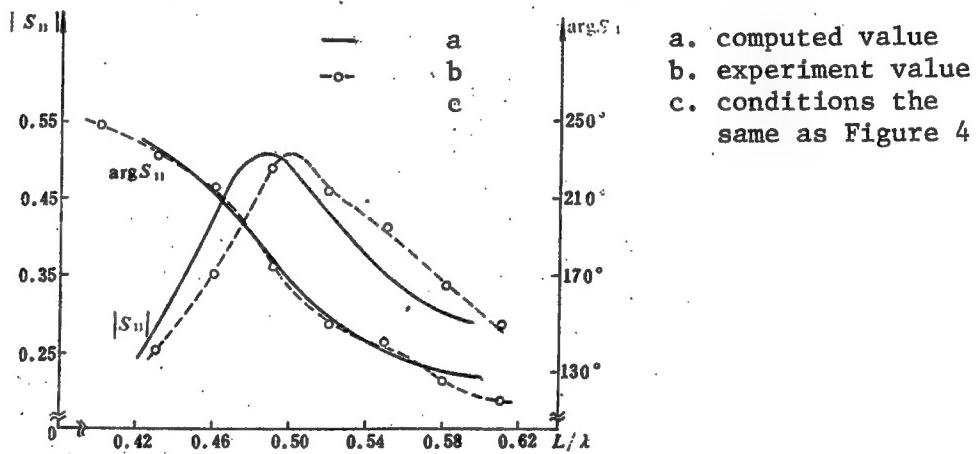


Figure 5. Curve of the relationship of twin slot reflection coefficient $|S_{11}|$ and slot length L

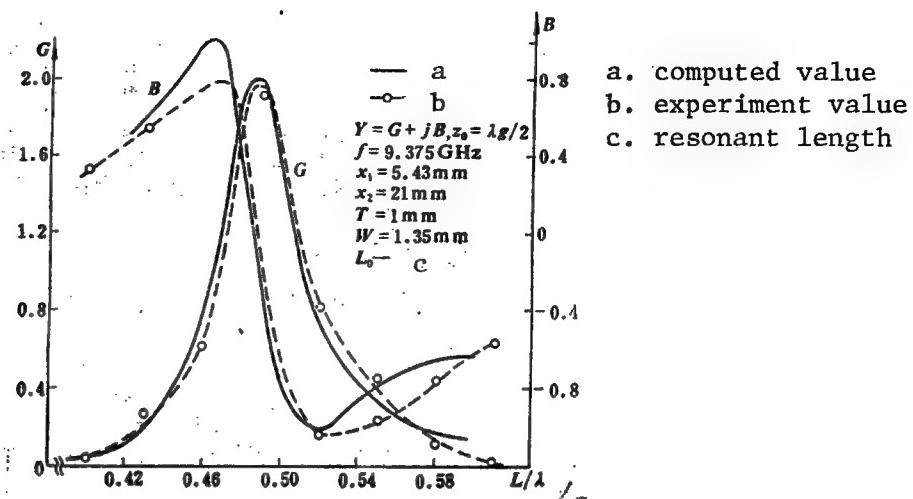


Figure 6. Curve of the relationship of twin slot equivalent admittance and slot length L

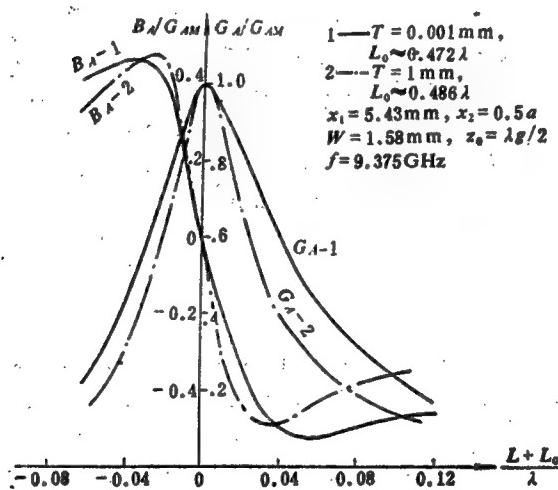


Figure 7. Curve of the relationship of slot A normalized admittance with wall thickness T and slot length L

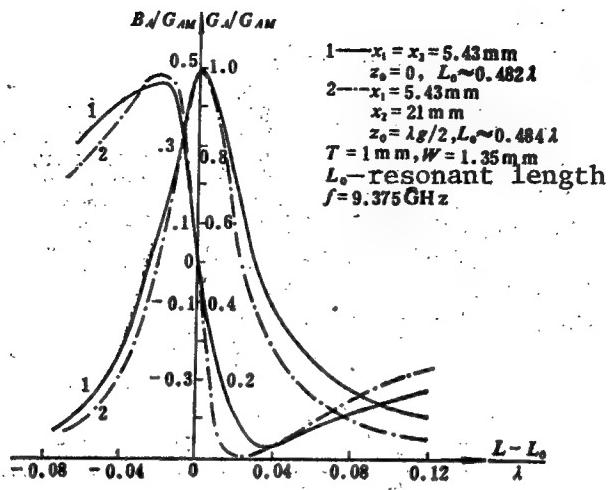


Figure 8. Curve of the relationship of slot A's admittance and slot B's drift

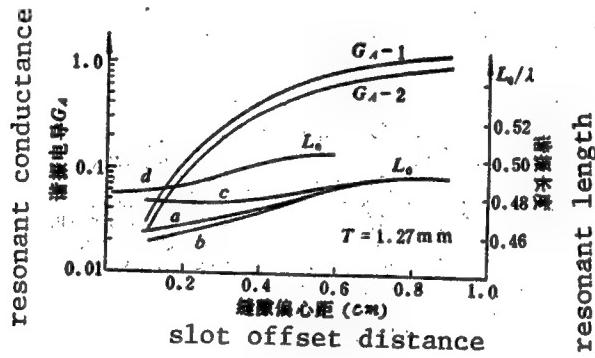
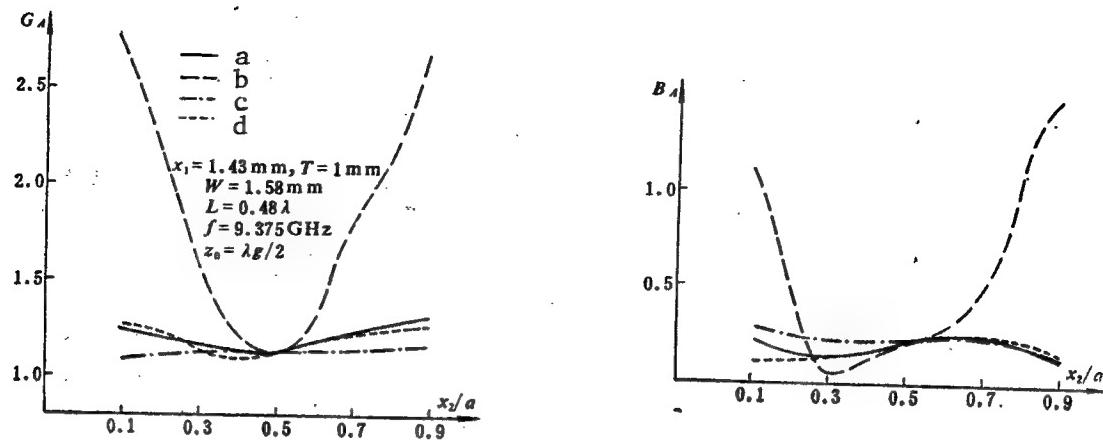


Figure 9. Curve of the relationship of slot A's resonant conductance G_A , resonant length L_0/λ and slot offset distance*

* G_A -1 is the curve ($x_2=21\text{mm}$, $z_0=\lambda g/2$) of the calculation of slot resonance conductance G_A when calculating mutual coupling in this article; G_A -2 is the calculation of an individual slot by this article and documents [1], [5], and [6]. In them, a belongs to [5]; b is this article's calculation of resonance length of an individual slot; c is this article's calculation of the resonance length of slot A when calculating mutual coupling; d is the document [5]'s curve of the resonance length of an individual semi-circular slot.



- a. contains coupling effect
- b. not counting mutual coupling inside waveguide
- c. not counting mutual coupling outside waveguide
- d. not counting high order mode coupling inside waveguide

Figure 10. Relationship of slot A conductance when coupling effects are computed and slot B drift

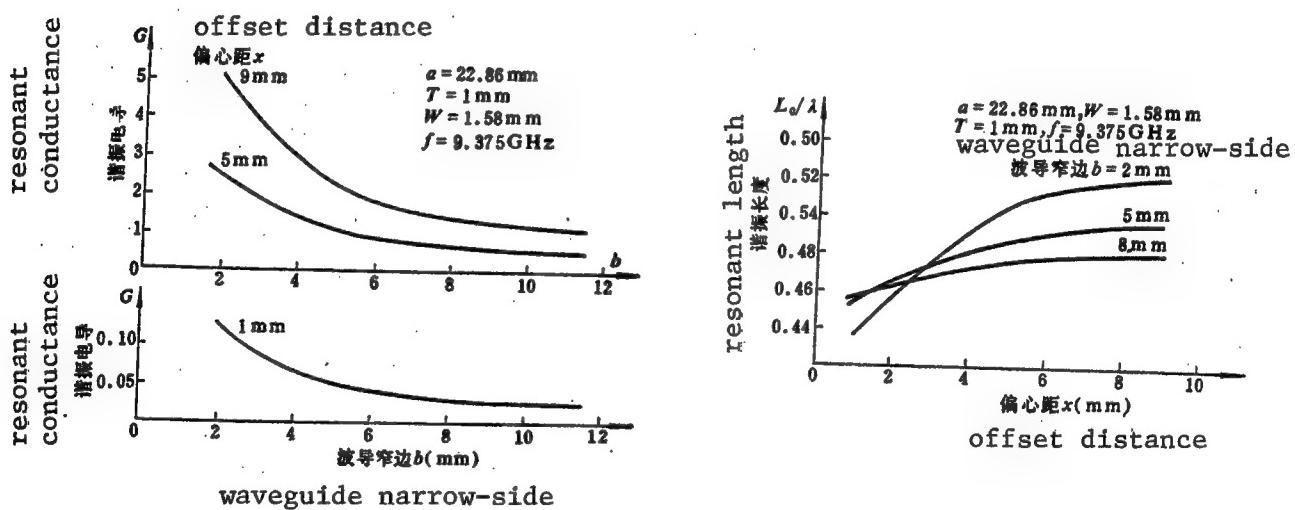


Figure 11. G-b characteristics of independent slot and characteristics of L_0/λ .

Figure 3 is the curve of calculations of the electrical field distribution tangential to the slot aperture surface. When slot length $L < 0.5\lambda$, the ratio of the secondary harmonic and the base wave amplitude is less than 0.08, the aperture field can be known as the cosine distribution. The thickness of the waveguide walls plays a decay role in the slot field, but when $T=1\text{mm}$ approximately, the influence is not great. The mutual coupling effect diminishes the aperture surface field base wave amplitude and increases the secondary harmonic amplitude.

Figures 4 and 5 are computed and experimental values of S parameter, the two basically fit. We also carried out calculations on the S parameter using the conditions of document [4], the results fit with Kay's [4] experimental values.

Figure 6-8 are the equivalent admittance characteristics of the slots. Figure 7 shows that the waveguide wall thickness narrows the frequency band and increases the length of the resonance. From Figure 8 it can be seen that mutual coupling narrows the frequency band and lengthens the resonance (see Figure 9).

Figure 9 is the curve of the relationship of the resonant conductance and resonant length with the slot's offset distance. Comparing this with the results of document [5], the resonant length difference is about 1 percent, and the resonant conductances are the same. When computing the mutual coupling under the conditions in the note to the figure* the resonant conductance increased.

Figure 10 shows that under the conditions given in this paper, waveguide internal mutual coupling has a clear influence on admittance characteristics: including, primary mode plays an important role, external mutual coupling is next, higher modes are minimal and can even be overlooked. Figure 11 is the relationship between resonant conductance G and resonant length L_0/λ with offset distance x and the dimensions of the waveguide's narrow side b . It can be seen that when x and b are both small, the resonant length is sensitive to offset distance x ; at this time it is appropriate to use a larger slot.

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* G_A-1 is the curve ($x_2=21\text{mm}$, $z_0=\lambda g/2$) of the calculation of slot resonance conductance G_A when calculating mutual coupling in this article; G_A-2 is the calculation of an individual slot by this article and documents [1], [5], and [6]. In them, a belongs to [5]; b is this article's calculation of resonance length of an individual slot; c is this article's calculation of the resonance length of slot A when calculating mutual coupling; d is the document [5]'s curve of the resonance length of an individual semi-circular slot.

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8226/12712
CSO: 4008/1031

APPLIED SCIENCES

RADAR ANTENNA TRANSIENT EFFECTS STUDIED

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 11, No 6, Nov 83 pp 80-87

[Article by Hu Hannan [5170 3352 0589] of Shanghai Ship & Shipping Research Institute: "End-fed Array Antenna Transient Effects and Their Effect on Angular Revolution"]

[Text] Abstract: The problem of transient effect of one-dimensional end-fed array antennas is discussed. It is shown that the transient effect of end-fed array antennas will deteriorate the angular resolution performance in radar systems, and that such influence is more serious to the radars sensitive to the amplitudes of very short pulses.

Chapter 13 of Skolnik [1] has a concise discussion on the problem of the pulse energy gain function for one-dimensional end-fed array antennas. As for the results produced by constant excitation, that reference also cites the pulse energy directivity graph for constant excitation and cosine excitation produced by the data in Wheeler [2]. This paper studies the transient effects of one-dimensional end-fed array antennas under arbitrary excitation amplitude aperture distribution, as well as discusses functions for antenna instantaneous power gain functions for the maximum value for antenna instantaneous power gain, and relations between those functions and between them and functions for antenna steady state power gain; particular results are produced for the distribution of constant excitation, cosine excitation, and the $I_0(A\sqrt{1-v^2})$ excitation actually often used; finally there is an analysis of the effects of antenna transient effects on angular resolution.

I. The Transient Effects of Arbitrary Excitation

When one-dimensional array antennas receive RF pulse signal excitation, the function for instantaneous power gain is (cf. Figures 21 and 23 in Chapter 13 of reference [1])

$$G_p(\theta, t) = \frac{2\pi WL}{\lambda^2} \frac{\left| \int_{-1}^{2\pi/T_p} A(v, \omega, t) e^{j\theta v} dv \right|^2}{\int_{-1}^1 |A(v, \omega)|^2 dv} \quad (1)$$

*Received in June 1982, finalized in January 1983.

In the equation, when the RF angular frequency is ω , $A(v, \omega, t)$ is the antenna aperture radiating function for the normalized distance $v=2x/L$ along the direction of the length of the antenna at time t ; x is the actual distance where the antenna center is the point of origin; L is the length of the antenna aperture; when the angular frequency is ω , $A(v, \omega)$ is the aperture steady state radiating function at location v ; $u=\pi L \sin \theta / \lambda$, θ is the space angle, λ is the RF wavelength; T_a is the time for the RF pulse to be transmitted from one end of the antenna to the other end; W is the width of the antenna aperture.

Under conditions of rectangular RF pulse excitation, let the envelope be $\text{rect}(t/T_s)$, assume that the width is $T_s > T_a$, the RF frequency is equal to the antenna center frequency (the steady-state dominant wave beamed toward the normal line), then

$$A(v, \omega, t) = \begin{cases} B(v) & |t| \leq T_s/2, -1 \leq v \leq 2t/T_s \\ & T_s/2 \leq t \leq T_s - T_s/2, |v| \leq 1 \\ & |t - T_s| \leq T_s/2, 2(t - T_s)/T_s \leq v \leq 1 \\ 0 & \text{the remainder} \end{cases} \quad (2)$$

$$A(v, \omega) = B(v) \quad |v| \leq 1 \quad (3)$$

In this we take the time when the leading edge of the pulse reaches the center of the antenna as the point of origin for t ; $B(v)$ is the amplitude distribution for the antenna aperture normalized excitation (this paper only discusses in-phase excitation). Therefore, we can rewrite equation (1) as the product of the antenna steady-state maximum gain G_{\max} and the normalized instantaneous power gain function $g_p(\theta, t)$:

$$G_p(\theta, t) = G_{\max} g_p(\theta, t) \quad (4)$$

where $G_{\max} = \frac{2\pi W L}{\lambda^2} \left| \int_{-1}^1 B(v) dv \right|^2 / \left| \int_{-1}^1 B^2(v) dv \right|^2 \quad (5)$

$$g_p(\theta, t) = \begin{cases} g_t(\theta, t), & |t| \leq T_s/2 \\ g(\theta), & T_s/2 \leq t \leq T_s - T_s/2 \\ g_t(\theta, T_s - t) & |t - T_s| \leq T_s/2 \end{cases} \quad (6)$$

in which, $g_t(\theta, t)$ and $g_t(\theta, T_s - t)$ are the transient state portion of $g_p(\theta, t)$; $g(\theta)$ is the steady-state portion, called the normalized steady-state power gain function:

$$g_t(\theta, t) = \frac{\left| \int_{-1}^t B(v) e^{i \omega v} dv \right|^2}{\left| \int_{-1}^1 B(v) dv \right|^2}, \quad |\tau| = \left| \frac{2t}{T_s} \right| \leq 1 \quad (7)$$

$$g(\theta) = \frac{\left| \int_{-1}^1 B(v) e^{i \omega v} dv \right|^2}{\left| \int_{-1}^1 B(v) dv \right|^2} = g_t\left(\theta, \frac{T_s}{2}\right) \quad (8)$$

In the normal direction: $g(0)=1$

$$g_s(0, t) = \left| \int_{-1}^t B(v) dv \right|^2 / \left| \int_{-1}^t B(v) dv \right|^2$$

Ordinarily, $B(v)$ is continuous and bounded, and $B'(v)$ and $B''(v)$ are also piecewise bounded, at which time it can be proven that:

$$g_s(\theta, t) \rightarrow \frac{B^2(-1) + B^2(t) - 2B(-1)B(t) \cos(1+t)u}{\left| \int_{-1}^t B(v) dv \right|^2 u^2}, \quad u \rightarrow \infty \quad (9)$$

In general, $B(v)$ is a paired function, and if at this time there are the properties mentioned above, then

$$g(\theta) \rightarrow \frac{4B^2(1)}{\left| \int_{-1}^1 B(v) dv \right|^2} \frac{\sin^2 u}{u^2}, \quad u \rightarrow \infty \quad (10)$$

When the function for the normalized instantaneous power gain maximum value $g_m(\theta)$ is $g_p(\theta, t)$ or $g_t(\theta, t)$ for the maximum value function of t , obviously

$$g_m(\theta) > g(\theta)$$

Generally, $B(v)$ is the monotonic non-increasing function of $|v|$, which if at this time it is still a paired function, then we can show:

$$g_m(\theta) = g(\theta), \quad u \leq \pi/2 \quad (11)$$

If $B(v)$ is continuous and bounded, and if there are also piecewise bounded $B'(v)$ and $B''(v)$, and moreover they are monotonic non-increasing functions of $|v|$, then

$$g_m(\theta) \rightarrow \left[\frac{B(-1) + B(0)}{\int_{-1}^1 B(v) dv} \right]^2 \frac{1}{u^2}, \quad u \rightarrow \infty \quad (12)$$

The pulse energy gain function for one-dimensional end-fed array antennas under RF pulse signal excitation

$$G_s(\theta) = \frac{2\pi WL}{\lambda^2} \frac{\int_{-\infty}^{\infty} \left| \int_{-1}^1 A(v, \omega, t) e^{j\omega v} dv \right|^2 dt}{\int_{-\infty}^{\infty} \int_{-1}^1 |A(v, \omega, t)|^2 dv dt} \quad (13)$$

under conditions of rectangular RF pulse excitation (with conditions similar to those above)

$$G_s(\theta) = \frac{2\pi WL}{\lambda^2} \frac{\frac{2}{\lambda^2} \int_{-T_s/2}^{T_s/2} \left| \int_{-1}^{2t/T_s} B(v) e^{j\pi v} dv \right|^2 dt + \int_{T_s/2}^{T_s - T_s/2} \left| \int_{-1}^1 B(v) e^{j\pi v} dv \right|^2 dt}{2 \int_{-T_s/2}^{T_s/2} \int_{-1}^{2t/T_s} B^2(v) dv dt + \int_{T_s/2}^{T_s - T_s/2} \int_{-1}^1 B^2(v) dv dt} \quad (14)$$

We have already assumed that here $B(v)$ is a paired function, and consequently is equal to the corresponding integration in the buildup and decay times of the antenna excitation. The equation above may be rewritten as

$$G_s(\theta) = G_{\max} g_s(\theta) \quad (15)$$

$$\text{where } g_s(\theta) = g(\theta) - \frac{T_s}{T_s} \left[g(\theta) - \int_{-1}^1 g_s(\theta, t) d\tau \right], \quad \frac{T_s}{T_s} \leq 1 \quad (16)$$

is the function for normalized pulse energy gain, in which the first term on the right is the steady-state portion, and the second term is the transient portion. Note that in equation (6) there is

$$g_s(\theta) = \frac{1}{T_s} \int_{-T_s/2}^{T_s + T_s/2} g_s(\theta, t) dt \quad (17)$$

In the normal direction,

$$g_s(0) = 1 - \frac{T_s}{T_s} \left[1 - \int_{-1}^1 g_s(0, t) d\tau \right], \quad \frac{T_s}{T_s} \leq 1 \quad (18)$$

It is easy to prove, if $B(v)$ is a paired function, then $g(\theta)$, $g_t(\theta, t)$, $g_p(\theta, t)$, $g_m(\theta)$, $g_e(\theta)$ and $G_p(\theta)$ are all paired functions of θ or u .

II. The Transient Effects of Constant Excitation, Cosine Excitation and $|I_0(\Delta\sqrt{1-u^2})|$ Excitation

1. Constant Excitation. At this time

$$B(v) = 1, \quad |v| \leq 1 \quad (19)$$

$$G_{\max} = 4\pi WL/\lambda^2 \quad (20)$$

$$g(\theta) = \sin^2 u/u^2 \quad (21)$$

$$g_s(\theta, t) = \sin^2 \left(\frac{1+t}{2} u \right) / u^2 \quad (22)$$

$$g_m(\theta) = \begin{cases} \sin^2 u/u^2, & u \leq \pi/2 \\ 1/u^2, & u \geq \pi/2 \end{cases} \quad (23)$$

That is, when $u \leq \pi/2$, $g_m(\theta) = g(\theta)$; when $u \geq \pi/2$, $g_m(\theta)$ is the envelope of $g_s(\theta)$;

• In reference [1]: Eq. (29) of Chapter 13 is in error.

$$g_e(\theta) = \frac{\sin^2 u}{u^2} - \frac{T_s}{T_a} \left[\frac{\sin^2 u}{u^2} - \frac{1}{u^2} \left(1 - \frac{\sin 2u}{2u} \right) \right], \quad \frac{T_s}{T_a} \leq 1 \quad (24)$$

In the normal direction,

$$g_e(0) = 1 - \frac{1}{3} \frac{T_s}{T_a}, \quad \frac{T_s}{T_a} \leq 1 \quad (25)$$

When $u \rightarrow \infty$

$$g_e(\theta) \rightarrow \frac{\sin^2 u}{u^2} + \frac{T_s}{T_a} \frac{\cos^2 u}{u^2}, \quad \frac{T_s}{T_a} \leq 1 \quad (26)$$

Figure 1 is a graph of $g_p(\theta, t)$ during buildup time and partial steady-state times when values of u are different, and Figure 2 is a graph of $g_e(\theta)$ for u when $g(\theta)$, $g_m(\theta)$, and there are different values for T_a/T_s .

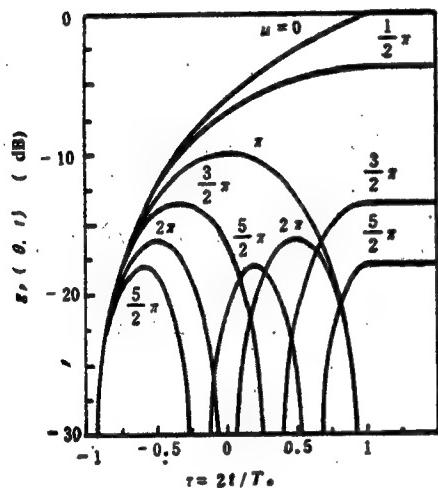


Figure 1. $g_p(\theta, t)$ for constant excitation

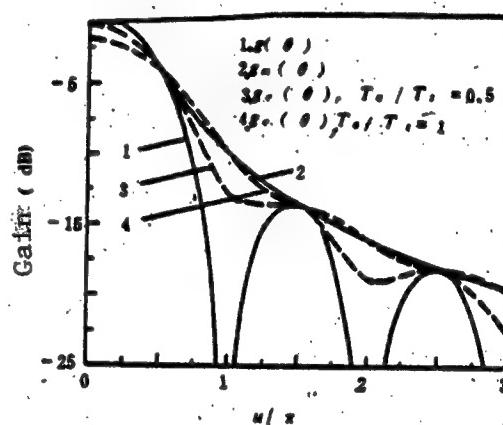


Figure 2. $g(\theta)$, $g_m(\theta)$ and $g_e(\theta)$ for constant excitation

2. Cosine Excitation. At this time

$$B(v) = \cos \frac{\pi}{2} v, \quad |v| \leq 1 \quad (27)$$

$$G_{\max} = \frac{8}{\pi^2} \frac{4\pi WL}{\lambda^2} \quad (28)$$

• In reference [1]: Eq. (30) of Chapter 13 is in error. Also,
In reference [3]: Eq. (2.57) is in error.

$$g(\theta) = \cos^2 u / \xi^2 \quad (29)$$

in which

$$\xi = 1 - 4u^2 / \pi^2$$

$$g_p(\theta, t) = \frac{1 + \sin^2 \frac{\pi}{2} \tau + \frac{4u^2}{\pi^2} \cos^2 \frac{\pi}{2} \tau}{4\xi^2} + \frac{2 \cos(1+\tau)u \sin \frac{\pi}{2} \tau - \frac{4u}{\pi} \sin(1+\tau)u \cos \frac{\pi}{2} \tau}{4\xi^2} \quad (30)$$

$$g_m(\theta) \begin{cases} = \cos^2 u / \xi^2, & u \leq \pi/2 \\ \rightarrow \pi^2 / 16u^2, & u \rightarrow \infty \end{cases} \quad (31)$$

$$g_e(\theta) = \frac{\cos^2 u}{\xi^2} - \frac{T_s}{T_r} \left[\frac{\cos^2 u}{\xi^2} + \frac{4u \sin 2u}{\pi^2 \xi^3} - \frac{0.75 + u^2 / \pi^2}{\xi^2} \right] \quad (32)$$

In the normal direction

$$g_e(0) = 1 - (T_s / 4T_r), \quad T_s / T_r \leq 1 \quad (33)$$

$$\text{When } u \rightarrow \infty \quad g_e(\theta) \rightarrow \frac{T_s}{T_r} \frac{\pi^2}{16u^2}, \quad T_s / T_r \leq 1 \quad (34)$$

See Figure 3 for the graph of $g_p(\theta, t)$, and see Figure 4 for the graphs of $g(\theta)$, $g_m(\theta)$, and $g_e(\theta)$.

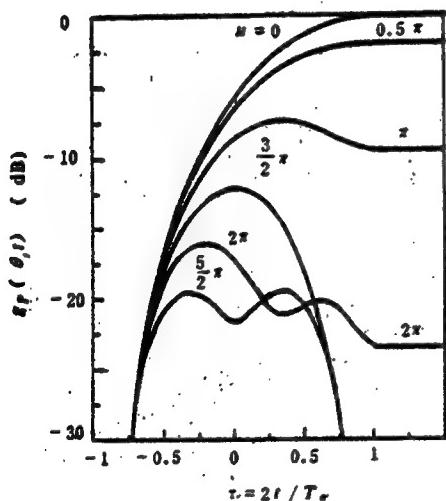


Figure 3. $g_p(\theta, t)$ for cosine excitation

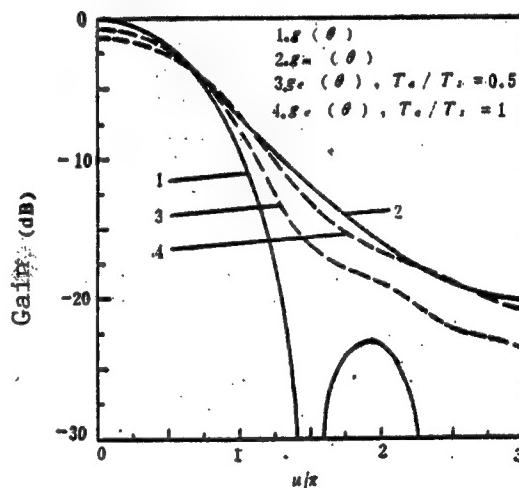


Figure 4. $g(\theta)$, $g_m(\theta)$, and $g_e(\theta)$

3. $I_0 (A\sqrt{1-v^2})$ Excitation. At this time

$$B(v) = \frac{1}{2} I_0 \left(A\sqrt{1-v^2} \right), \quad |v| \leq 1 \quad (35)$$

$$g(\theta) = \frac{A^2}{\sin^2 A} \frac{\sin^2 \sqrt{u^2 - A^2}}{u^2 - A^2} \quad (36)$$

But it is difficult to obtain an accurate expression for G_{\max} , $g_t(\theta, t)$, $g_m(\theta)$, and $g_e(\theta)$. Consequently, equation (35) can be more or less approximated with the following simple periodic excitation*

$$B^*(v) = a + b \cos cv, \quad |v| \leq 1 \quad (37)$$

in which

$$\left. \begin{aligned} c &= 2 \arccos \left[\frac{1}{2} \frac{B(0) - B(1)}{B(0) - B(\frac{1}{2})} - 1 \right] \\ b &= \frac{B(0) - B(1)}{1 - \cos c}, \quad a = B(0) - b \end{aligned} \right\} \quad (38)$$

We can point out at the same time that constant excitation, cosine excitation, and cosine square excitation are all examples of this kind of simple periodic excitation; they may also be used for approximations of multi-type excitation. Using the approximation excitation formula (37) we can obtain approximation expressions for G_{\max} , $g(\theta)$, $g_t(\theta, t)$, $g_m(\theta)$, and $g_e(\theta)$:

$$G_{\max}^* = \frac{\left(a + b \frac{\sin c}{c} \right)^2}{a^2 + 2ab \frac{\sin c}{c} + \frac{b^2}{2} \left(1 + \frac{\sin 2c}{2c} \right)} \frac{4\pi WL}{\lambda^2} \quad (39)$$

$$g^*(\theta) = \left[\frac{a \frac{\sin u}{u} + b \frac{u \sin u \cos c - c \sin c \cos u}{u^2 - c^2}}{a + b \frac{\sin c}{c}} \right]^2 \quad (40)$$

$$\begin{aligned} g_t^*(\theta, t) &= \frac{1}{4} \left(a + b \frac{\sin c}{c} \right)^2 \\ &\times \left\{ \left[a \frac{\sin u + \sin ut}{u} + b \frac{u(\sin u \cos c + \sin ut \cos ct) - c(\cos u \sin c + \cos ut \sin ct)}{u^2 - c^2} \right]^2 \right. \\ &\left. + \left[a \frac{\cos u - \cos ut}{u} + b \frac{u(\cos u \cos c - \cos ut \cos ct) + c(\sin u \sin c - \sin ut \sin ct)}{u^2 - c^2} \right]^2 \right\} \quad (41) \end{aligned}$$

$$g_m^*(\theta) = \begin{cases} = g^*(\theta), & u \leq \pi/2 \\ \rightarrow \left[\frac{a + \frac{b}{2}(1 + \cos c)}{a + b \frac{\sin c}{c}} \right]^2 \frac{1}{u^2}, & u \rightarrow \infty \end{cases} \quad (42)$$

* Corresponding symbols are all distinguished by the addition of an "*".

$$\begin{aligned} \int_{-1}^1 g_e^*(\theta, t) d\tau = & \frac{1}{4(a+b\frac{\sin c}{c})^2} \left\{ \frac{4a^2}{u^2} \left(1 - \frac{\sin 2u}{2u}\right) \right. \\ & + \frac{b^2}{(u^2-c^2)^2} \left[(u^2+c^2) \left(2 + \frac{\sin 2c}{2c}\right) + (u^2-c^2) \cos 2c - u \sin 2u - (u-c)^2 \frac{\sin 2(u+c)}{2(u+c)} \right. \\ & - (u+c)^2 \frac{\sin 2(u-c)}{2(u-c)} \left. \right] - \frac{2ab}{u(u^2-c^2)} \left[\left(\frac{1-\cos 2u}{u} - \frac{2u}{u^2-c^2}\right) c \sin c - 2u \left(\cos c + \frac{\sin c}{c}\right. \right. \\ & \left. \left. - \cos c \frac{\sin 2u}{2u}\right) + (u-c) \frac{\sin(2u+c)}{2(u+c)} + (u+c) \frac{\sin(2u-c)}{2(u-c)} \right] \} \end{aligned} \quad (43)$$

Substituting equations (40) and (43) into equation (16) we can obtain $g_e^*(\theta)$. In the normal direction

$$g_e^*(0) = 1 - \frac{T_s}{T_s} \left[\frac{1}{2} - \frac{\frac{2a^2}{3} + \frac{4ab}{c^2} \left(\frac{\sin c}{c} - \cos c\right) + \frac{b^2}{c^2} \left(1 - \frac{\sin 2c}{2c}\right)}{4 \left(a+b\frac{\sin c}{c}\right)^2} \right], \quad \frac{T_s}{T_s} \leq 1 \quad (44)$$

When $u \rightarrow \infty$

$$\begin{aligned} g_e^*(\theta) \rightarrow & \left(\frac{a+b \cos c}{a+b \frac{\sin c}{c}} \right)^2 \left\{ \frac{\sin^2 u}{u^2} \right. \\ & \left. - \frac{T_s}{T_s} \left[\frac{\sin^2 u}{u^2} - \frac{a^2 + \frac{b^2}{4} \left(2 + \cos 2c + \frac{\sin 2c}{2c}\right) + ab \left(\cos c + \frac{\sin c}{c}\right)}{(a+b \cos c)^2 u^2} \right] \right\}, \quad \frac{T_s}{T_s} \leq 1 \end{aligned} \quad (45)$$

Below is the specific result of calculation in an example where $A=3.214$. At this time

$$B^*(v) = 1.4649 + 1.4421 \cos 2.3037v, \quad |v| \leq 1 \quad (46)$$

The maximum relative error of this for equation (35) is 0.86 percent, and root-mean square relative error is 0.34 percent;

$$G_{\max}^* = 0.8615 \times 4\pi WL/\lambda^2 \quad (47)$$

$$g_m^*(\theta) \begin{cases} = g^*(\theta), & u \leq \pi/2 \\ \rightarrow 0.7790/u^2, & u \rightarrow \infty \end{cases} \quad (48)$$

$$g_e^*(0) = 1 - 0.2661 T_s / T_s, \quad T_s / T_s \leq 1 \quad (49)$$

$$g_e^*(\theta) \rightarrow 0.0671 \frac{\sin^2 u}{u^2} - \frac{T_s}{T_s} \left(0.0671 \frac{\sin^2 u}{u^2} - 0.6139 \right), \quad u \rightarrow \infty \quad \frac{T_s}{T_s} \leq 1 \quad (50)$$

For the graph of $g_p^*(\theta, t)$ see Figure 5; Figure 6 is the graph of $g^*(\theta)$, where within plotting accuracy equation (36) is completely coincidental with it, so this graph also plots $g_m^*(\theta)$ and $g_e^*(\theta)$.

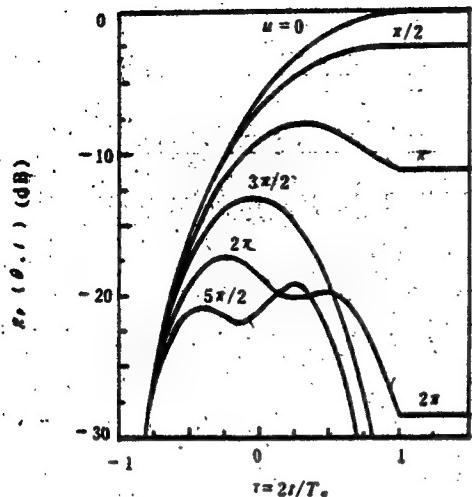


Figure 5. $g^*(\theta, t)$ for $I_0(3.214\sqrt{1-v^2})$ excitation

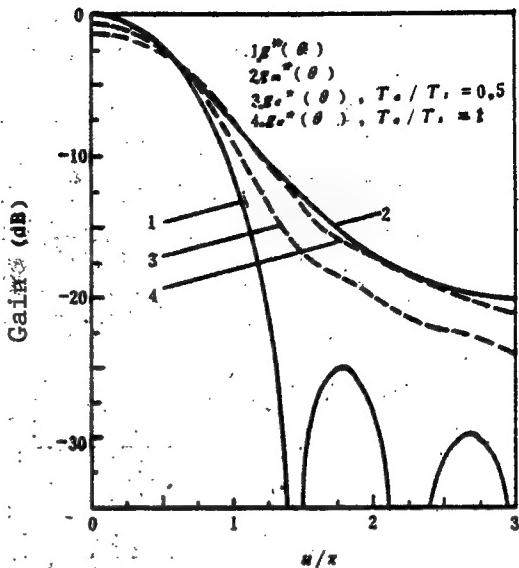


Figure 6. $g^*(\theta)$, $g_m^*(\theta)$ and $g_e^*(\theta)$ for $I_0(3.214\sqrt{1-v^2})$ excitation

III. The Effects on Angular Resolution

It can be seen from the preceding that the transient effects of end-fed array antennas cause a decline in the maximum value of pulse energy gain, that they cause an increase in the half-power width of pulse energy directivity graphs, that they cause the main and sidelobes of pulse energy directivity graphs to form one surface, and that they can also cause a rise in "sidelobe" levels. Consequently, as far as pulse energy sensitive radar is concerned, antenna transient effects will cause a decrease in the maximum functional distance, a worsening of angular resolution, and will also introduce a great amount of clutter. In order to quantitatively calculate the angular resolution of an antenna, Figures 7 and 8 give rating curves for half-power width Δu [the width when $g_e(\theta)$ descends to $g_e(0)/2$] and expansion coefficient $\Delta/\Delta u_0(T_a/T_s=0)$ and T_a/T_s antenna pulse energy directivity graph. It is worth noting that under conditions of constant excitation, only when $T_a/T_s=2/9$ is the first minimum point 3 dB lower than the first lobe of $g_e(\theta)$, that is, only at this time can the pulse energy directivity graphs begin to be similar to the steady-state directivity graph; under conditions of cosine excitation, the value of T_a/T_s is $32/675 \approx 1/20$; under conditions of $I_0(3.214\sqrt{1-v^2})$ excitation, this T_a/T_s value eventually reaches $1/30$.

It can also be seen from the preceding that in the transient process end-fed array antennas produce transient pulses, the order of magnitude of the width being T_a , and the maximum amplitude value can be much greater than the steady-state value. Although the half-power width of the maximum instantaneous power directivity graph is equal to or approximates the steady-state power directivity graph, there is in the former absolutely no distinction between main and sidelobes. Moreover, when u is great, there is inverse decay with u^2 . Consequently, as for radars sensitive to narrow pulse amplitude, antenna transient

effects will introduce serious transient echo phenomena. Figure 9 is an image photographed in the field of a certain radar using long end-fed slot antenna, where in both directions beginning from bow and stern of a medium-size ship 1.7 nautical miles away there is approximately 20° of isolated clutter, caused by this kind of transient echo.

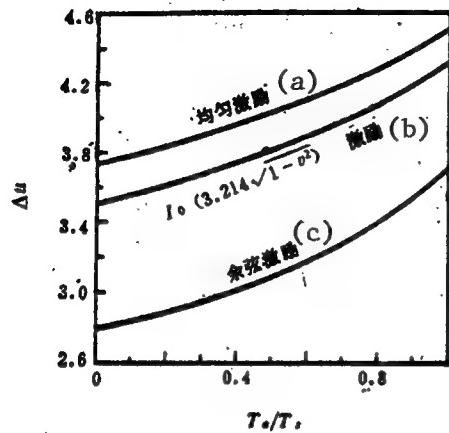


Figure 7. End-fed array antenna half-power width

Key:

- a. Constant excitation
- b. $I_0(3.124\sqrt{1-v^2})$ excitation
- c. Cosine excitation

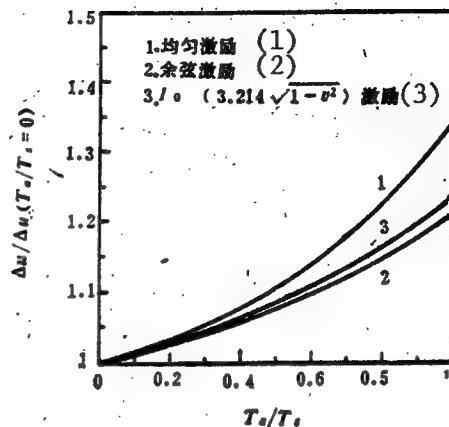


Figure 8. End-fed array antenna expansion coefficient

Key:

- 1. Constant excitation
- 2. Cosine excitation
- 3. $I_0(3.124\sqrt{1-v^2})$



Figure 9. The phenomenon of isolated clutter caused by antenna transient effects, where V is normal echo and between the ↑↑ is isolated clutter

An explanation of the isolated clutter phenomenon of Figure 9: When a large or medium size vessel is positioned within several nautical miles in a transverse direction, it will always produce the phenomenon of isolated clutter. Calculations prove that this phenomenon is not caused by antenna steady-state sidelobes, but rather by antenna transient echo.

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12586/6091
CSO: 4008/1030

LARGE SIGNAL THEORY, COMPUTATION OF COUPLED-CAVITY TWT'S

Beijing DIANZI XUEBAO [ACTA ELECTRONICA SINICA] in Chinese Vol 12 No 3, May 84 pp 25-32

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[Text] English Abstract: The physical model and numerical method for CCTWT's large-signal interaction are given. In this model, the electrical field distribution in the gap (both modulus and phase angle) as well as the backward wave influence and the relativistic effect are considered. And the mechanism of the electron beamwave interaction is discussed in great detail. Since the model uses the energy conservation law as a rule for the interaction, the computational results conform with the law accurately. The computation for an X-band CCTWT shows good agreement with the experiment values.

I. Introduction

When discussing interaction, the coupled-cavity TWT theory put forth by Pierce^[1] considers only the synchronous space harmonics of electron beams and ignores its other space harmonics, thus there is a very great discrepancy with reality. Initially, Kino^[2] put forth an interactive model of a lumped parameter triple-port [sanduankou [0005 4551 0656]] network which was completely different from Pierce's model,^[1] but later some scholars carried out some explorations of triple port network interaction^[3,4] but it was impossible to find triple-port parameters that accurately reflected the interaction process of electron beams and waves. This is because the triple-port network which Kino used was theoretically only suited to linear problems of lumped parameters. Thus, people accepted the triple-port physical model but rejected the specific form of the triple-port network: i.e., two ports were used to represent the input and output coupling hole of a cavity, and a third port represented the interaction of the electron beam and the wave.. The relationship between the "waves" of these three ports is not determined by the network parameters of Kino's triple port network, but by a series of equations that describe transmission, wave control of the electron beam, and the electron beam's excitation of the wave. In the same period of work, Vaughan^[5] and ourselves^[6] adopted the above described method. The inadequacy of Vaughan's model is in viewing the port in which the electron beam excites the electromagnetic waves as a "lumped" port, when the electron beam which has been or-

*Received December 1982, finalized July of the same year.

ganized by the charge plate in one cycle goes through a cavity, it only excites the field in a "lumped" fashion in the center of the gap; but reference [6] takes distributed excitation into account, i.e., the cavity gap is not viewed as a lumped port, but as a distributed one. However, reference [6] has not yet completed program debugging and computational work. Connolly's [7] work is now the best coupled-cavity TWT large-signal theory. The work in this paper was carried out on the foundation of references [6] and [7].

II. Basic Physical Model

The basic physical model of interaction is illustrated in Figure 1. The voltage \dot{V} (including forward wave and backward wave) in the illustration has a dual significance: on the one hand it represents the voltage at the gap, and through the Kosmahl [8] model, the electrical field distribution in the entire drift tube can be found using this voltage; on the other hand it is also a representation of power flow, similar to the wave parameters in a scatter matrix. The relationship of \dot{V} and power flow P is defined as:

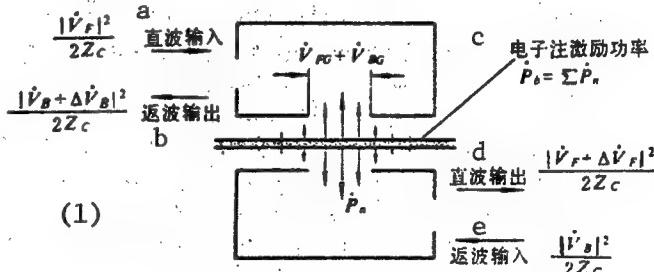
$$P = |\dot{V}|^2 / 2Z_c \quad (1)$$

in which, Z_c is the overall interaction impedance. Figure 1 also illustrates the electron beam and wave interaction situation: when there is no electron beam, $\Delta\dot{V} = 0$. Regardless of whether it is a forward wave or a backward wave, input and output are equivalent (overlooking loss), and the gap voltage \dot{V}_G at this time is also equal to \dot{V} . Z_c is generally computed through cold measurement [lengce [0397 3261]] [9]. In this way the relationship between the electrical field and the power flow can be established through an intermediate variable V .

Figure 1. Power flow relationship inside a cavity

Key:

- a. forward wave input
- b. backward wave output
- c. electron beam excitation power
- d. forward wave output
- e. backward wave input



1. Representation of High Frequency Field

According to the complex voltage \dot{V}_k (including forward wave voltage \dot{V}_{Fk} and backward wave voltage \dot{V}_{Bk}) of the k th cavity provided by Kosmahl's model, the average electrical field on an electrically charged plate of radius b_k , and thickness l_d can be represented as:

$$\dot{E}_{n,k} = \frac{\mu}{L_k l_k \sinh(\mu)} \sum_{m=-\infty}^{\infty} \frac{C_{mk}(\mu, \beta_{mk}) I_1(\gamma_{mk} b_k)}{\gamma_{mk} b_k I_0(\gamma_{mk} a_k)} \cdot \frac{\sin(\beta_{mk} l_k / 2)}{(\beta_{mk} l_k / 2)} \\ \cdot \operatorname{Re}\{[\dot{V}_{Fk} \exp(-i \beta_{mk} z) + \dot{V}_{Bk} \exp(i \beta_{mk} z)] \cdot \exp(i \omega t)\} \quad (2)$$

in which $C_{mk}(\mu, \beta_{mk}) = \frac{2l_k [\mu \sinh(\mu) \cos(\beta_{mk} l_k) + \beta_{mk} l_k \cosh(\mu) \sin(\beta_{mk} l_k)]}{\mu^2 + (\beta_{mk} l_k)^2}$

 $\beta_{mk} = \beta_{0k} + (2m\pi/L_k), \quad \gamma_{mk} = \sqrt{\beta_{mk}^2 - (\omega^2/c^2)}$

$\beta_0 L_k$ represents the shift of each cavity; M is the field coefficient; L_k is the cycle; $2l_k$ is the gap width; a_k is the drift tube radius; c is the velocity of light, let

$$\dot{E}_{n,k} = \operatorname{Re}[(\dot{Q}_{nk} \dot{V}_{Fk} + \dot{Q}_{nk}^* \dot{V}_{Bk}) \exp(i \omega t, (z_k))] \quad (3)$$

and comparing to
Eq. (2) we get

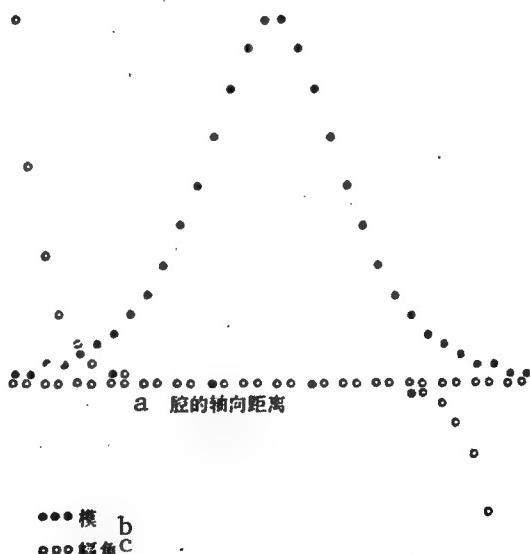
$$\dot{Q}_{nk} = \sum_{m=-\infty}^{\infty} \frac{\mu}{L_k l_k \sinh(\mu)} \cdot \frac{C_{mk} I_1(\gamma_{mk} b_k)}{\gamma_{mk} b_k I_0(\gamma_{mk} a_k)} \left(\frac{\sin(\beta_{mk} l_k / 2)}{(\beta_{mk} l_k / 2)} \right) \\ \cdot \exp(-i \beta_{mk} y_{nk}) \quad (4)$$

in which y_{nk} is the local coordinates of the k th cavity with the center of the gap as the point of origin, the subscript k indicates that our model permits cavities and electron beam radii to be changeable. For the majority of intermediate cavities, when $\mu = 0.7$, the \dot{Q}_{nk} modulus and phase angle are as illustrated in Figure 2. This is the result computed when m takes ± 10 harmonic waves. The error at this time was less than 10^{-6} .

Figure 2. Modulus and phase angle
of field shape function
 \dot{Q}_{nk}

Key:

- a. axial distance of cavity
- b. modulus
- c. phase angle



2. Space Electron Field

Finding the space charge in problems in which distance is an independent variable was solved in physics and mathematics long ago. We adopted Green's function for high electron beam models.

$$\text{For } |z| > l'_d: E_{sc} = \frac{4a^2 q_d \operatorname{sgn}(z)}{(l'_d)^2 b^2 \pi \epsilon_0} \sum_{m=1}^{\infty} \frac{[J_1(\lambda_m b/a)]^2}{\lambda_m^4 [J_1(\lambda_m)]^2} \left[\cosh\left(\frac{\lambda_m l'_d}{a}\right) - 1 \right] \cdot \exp\left(-\frac{\lambda_m |z'|}{a}\right) \quad (5)$$

$$\text{For } |z| < l'_d: E_{sc} = \frac{4a^2 q_d \operatorname{sgn}(z)}{(l'_d)^2 b^2 \pi \epsilon_0} \sum_{m=1}^{\infty} \frac{[J_1(\lambda_m b/a)]^2}{\lambda_m^4 [J_1(\lambda_m)]^2} \left[1 - \exp\left(-\frac{\lambda_m |z'|}{a}\right) - \exp\left(-\frac{\lambda_m l'_d}{a}\right) \cdot \sinh\left(\lambda_m \frac{|z'|}{a}\right) \right] \quad (6)$$

in which λ_m is the mth root of zero exponent Bessel function. q_d is the charge of the charged plate, l'_d and z' are the distance after relativistic theory correction and the thickness of the charged plate:

$$l'_d = l_d / \sqrt{1 - (u_0/c)^2}, \quad z' = z / \sqrt{1 - (u_0/c)^2} \quad (7)$$

U_0 is the electron forward flow velocity. For purposes of simplification, the subscript k has been left out of the above equations. To accelerate computing speed while maintaining precise conditions, we adopted the following: 1) first we set up a space charge table, then used the table in place of computing dot by dot. The grids on the table were not equidistant, and as the distances grew nearer the grids became denser; the number of terms accepted for high order harmonics at different distances were also not the same, maintaining precision at 10^{-6} . 2) We did not compute the space charge at every step, but once at every N steps, the point derived from computations was treated as a sample point of the space charge, the values of the space charges at other points was found by secondary extrapolation from these sample points; in every cavity, the precision of the interpolated points was checked and if the error exceeded the set value, N was automatically reduced by half.

3. Equation of Motion

Assuming that the force exerted within the region Δz in the charge plate does not change, we used the equation of uniformly accelerated motion and not the usual uniform velocity equation. Similarly, we dropped out the subscript k representing the number of cavities. Considering post-revision relativistic theory, the acceleration is:

$$a_n = -(E_{sc,n} + E_{rf,n}) \cdot \eta \cdot [1 - (v_n^2/c^2)]^{3/2} \quad (8)$$

$$v_{n+1} = v_n + a_n \Delta t \quad (9)$$

$$\Delta t = \Delta z / [(v_{n+1} + v_n)/2] \quad (10)$$

and combining Eqs. (9) and (10) and using $\varphi_{n+1} - \varphi_n$ to represent Δt , we get:

$$v_{n+1} = \sqrt{v_n^2 + 2a_n \Delta z} \quad (11)$$

$$\varphi_{n+1} = \varphi_n + 2\omega \Delta z / (v_{n+1} + v_n) \quad (12)$$

in which v_n , φ_n , v_{n+1} and φ_{n+1} represent respectively the initial and final speed and position of the nth step of the charge plate. n represents the discretization of z direction, the ultimate value of n is also the initial value of $n + 1$. Similar consideration is given to the relationship of kinetic power and the voltage as well as velocity of the charge plate after the relativistic effect, it was:

$$u_0 = c \sqrt{1 - \frac{1}{1 + (qV_0/m_0c^2)^2}} \quad (13)$$

$$P = m_0c^2 \left[\frac{1}{\sqrt{1 - (v^2/c^2)}} - 1 \right] \quad (14)$$

4. Electron Beam's Excitation of the Field

The electron beam's excitation of the field is the most difficult problem in large signal interaction theory. We first considered the forms which interaction should take from the perspective of the general laws of the conservation of energy. The relationship of the power flow is still as illustrated in Figure 1. Below we first compute the work done by the jth charge plate in the process of n step motion:

$$\Delta u_{j,n,k} = q_d \cdot E_{j,n,k} \cdot \Delta z \quad (15)$$

$$q_d = I_0/F \cdot N_d \quad (16)$$

in which, I_0 is the forward current, F is the frequency, N_d is the number of charge plates sampled in each cycle. When discussing excitation we did not consider space charge field. In the Δz region, E_{rf} is a constant for each charge plate. This coincides with the assumptions in the equation of motion. Substituting in Eq. (3) and Eq. (16) we get:

$$\Delta u_{j,n,k} = \frac{I_0}{FN_d} \text{Re}[(Q_{nk} \cdot V_{RFk} + Q_{nk}^* V_{BGk}) \cdot \exp(i\omega t_j(z_{nk}))] \Delta z \quad (17)$$

Integrating all the charge plates within one cycle and dividing it by the cycle we obtained the power P_{nk} of excitation in the process of the nth step of motion in the cavity, and then integrating in the entire cavity length, we obtained the power which the electron beam excited in the entire kth cavity. Distributed excitation is the primary difference between this mode and Vaughan's model. Because at each step distributed excitation has its own phase, we did not have to make any assumptions regarding the excitation phase.

$$P_{ck} = \frac{I_0}{2\pi} \int_{-L/2}^{L/2} \operatorname{Re} \left\{ (\dot{Q}_{nk} \dot{V}_{FGk} + \dot{Q}_{nk}^* \dot{V}_{BGk}) \cdot \left[\int_0^{2\pi} \exp i\varphi(\varphi_0, z) d\varphi_0 \right] \right\} dz \quad (18)$$

From Figure 1 it is easy to compute the difference of the electrical field energy of the flow in and out of k cavity, and through the complex number operation we get:

$$\begin{aligned} P_{ck} &= \frac{1}{2Z_c} [(\dot{V}_{Fk} + \Delta\dot{V}_{Fk})^2 - \dot{V}_{Fk}^2 + (\dot{V}_{Bk} + \Delta\dot{V}_{Bk})^2 - \dot{V}_{Bk}^2] \\ &= \frac{1}{Z_c} \operatorname{Re} \left[\left(\dot{V}_{Fk} + \frac{\Delta\dot{V}_{Fk}}{2} \right) \Delta\dot{V}_{Fk}^* + \left(\dot{V}_{Bk} + \frac{\Delta\dot{V}_{Bk}}{2} \right) \Delta\dot{V}_{Bk} \right] \end{aligned} \quad (19)$$

The conservation of energy demands that $P_c = P_b$, and since the forward wave and the backward wave are orthogonal, they should be equivalent, and the forward wave can be obtained:

$$\begin{aligned} \frac{1}{Z_c} \operatorname{Re} \left[\left(\dot{V}_{Fk} + \frac{\Delta\dot{V}_{Fk}}{2} \right) \cdot \Delta\dot{V}_{Fk}^* \right. \\ \left. = \frac{I_0}{2\pi} \operatorname{Re} \left\{ \dot{V}_{FGk} \int_{-L/2}^{L/2} \dot{Q}_{nk} \cdot \int_0^{2\pi} e^{i\varphi(\varphi_0, z)} d\varphi_0 dz \right\} \right] \end{aligned} \quad (20)$$

Eq. (20) is the criterion which interaction must observe when satisfying the relationship of conservation of energy. Just like the overwhelming majority of interaction phenomena, the conservation of energy is only a necessary condition and not a sufficient condition. Only under the simplest forms of motion can the conservation of energy criteria completely determine the form of interaction, but in most circumstances, just the conservation of energy alone is not sufficient to determine completely the form of interaction but must be aided by other restrictions, or other criteria, before it can completely determine the form of interaction. Interaction in a coupled-cavity TWT is one of these more complex forms. We must provide other criteria to determine the relationship of gap voltage \dot{V}_{FG} , pre-excitation input voltage \dot{V}_{Fk} , and the voltage increase produced by excitation $\Delta\dot{V}_{Fk}$. To determine precisely the relationship between \dot{V}_{FG} and \dot{V}_{Fk} and $\Delta\dot{V}_{Fk}$ in an excitation field, it is necessary to find the form of the excitation field and this is an extremely complex problem. We can only use approximate methods, and at first approximation, the gap voltage can be viewed as the average value of entry and exit voltages, i.e.,

$$\dot{V}_{FGk} = \dot{V}_{Fk} + \frac{1}{2} \Delta\dot{V}_{Fk} \quad (21)$$

and substituting Eq. (21) in Eq. (20), we get:

$$\Delta\dot{V}_{Fk} = \int_{-L/2}^{L/2} \dot{Q}_{nk}^* \left(\frac{I_0 Z_c}{2\pi} \int_0^{2\pi} e^{i\varphi(\varphi_0, z)} d\varphi_0 \right) dz \quad (22)$$

Similarly, for the backward wave we get:

$$\Delta \dot{V}_{Bk} = \int_{-L/2}^{L/2} Q_{nk} \left(\frac{I_0 Z_c}{2\pi} \int_0^{2\pi} e^{-i\varphi(\varphi_0, z)} d\varphi_0 \right) dz \quad (23)$$

III. Outline of the Program

Since people are already familiar with large signal computations of ordinary helix TWT or klystrons, there is nothing special about writing a program for space charge, equation of electron motion, and wave excitation. The primary problem in program design was the problem of identifying forward wave and backward wave transmission, superposition, iteration, and convergence. The equations for forward and backward wave transmission are as follows:

$$\dot{V}_{Fk} = \dot{V}_{F(k-1)} \cdot \exp(-i\beta_0 L_{k-1}) \cdot \exp(-\alpha_{k-1}) \quad (24)$$

$$\dot{V}_{Bk} = \dot{V}_{B(k+1)} \cdot \exp(-i\beta_0 L_{k+1}) \cdot \exp(-\alpha_{k+1}) \quad (25)$$

Each cycle is divided into N_d charge plates ($N_d = 24$), and each cavity is divided into 32 grids. Each step requires first computing the space charge and high frequency field, then computing the motion of the charge plate; through superposition of the charge plate phases of one cycle, a "convection current" was obtained, the "convection current" and the field shape coefficient were multiplied to obtain the contribution of each step towards the "excitation voltage"; after travelling one cavity, the contributions of each step were superposed, i.e., the "excitation voltages" \dot{V}_F and \dot{V}_B for the entire cavity were calculated. For this article a subroutine DVCV is used to represent this process.

Cavity Iteration: Because the $\Delta \dot{V}_F$ and $\Delta \dot{V}_B$ obtained through the DVCV process and the gap voltages \dot{V}_{FG} and \dot{V}_{BG} are related, and \dot{V}_{FG} also in turn are related to $\Delta \dot{V}_F$ and $\Delta \dot{V}_B$, this requires an iteration. In cavity iteration, we change only \dot{V}_{FG} and store $\Delta \dot{V}_B$, therefore, cavity iteration is also a problem of forward wave convergence. Computations show that forward wave convergence is not difficult, and generally with three iterations, the relative error of the phase and amplitude of $\Delta \dot{V}_F$ is less than 1 percent.

Backward Wave Superposition and Segment Iteration: According to the above process, computing from the first cavity to the last cavity of a segment, one obtains a $\{\Delta V_{Bk}\}$ number group. Then according to the equation

$$\dot{V}_{Bk} = \dot{V}_{B(k+1)} \cdot \exp(-i\beta_0 L_{k+1}) \cdot \exp(-\alpha_{k+1}) + \Delta \dot{V}_{Bk} \quad (26)$$

and letting input of the last cavity $\dot{V}_{B(k+1)}$ equal zero, one can compute from the last cavity back to the first cavity and obtain another number group $\{\dot{V}_{Bk}\}$. However, \dot{V}_{Bk} is not used in backward voltage of the gap of an electron beam. (25)

$$\dot{V}_{BGk} = \dot{V}_{Bk} - \frac{1}{2} \Delta \dot{V}_{Bk} \quad (27)$$

Adding the new \dot{V}_{BGk} and \dot{V}_{FGk} together and computing from the first cavity towards the last, is segment iteration. Segment iteration solves the problem of backward wave convergence. The best criterion of backward wave convergence is the value of the first cavity's backward wave, this is because it is the superposition of the backward waves of all the cavities. But in actual computations, the output voltage of the last cavity is also used as a criterion. We used the first cavity's backward wave value as the convergence criterion for the input segment, to ensure higher precision and the output power was the criterion of convergence for the output segment, to save on computer time.

Rectifier Iteration: Rectifier iteration is to select appropriate input power to ensure the circuit's output cavity work is near the saturation point. Because rectifier iteration is the loop at the most external layer, it uses a great deal of computer time and is not suited to multiple iterations. Actually, it is only for suitable adjustment of the input power to guarantee that the difference between the gain of the last cavity and the maximum gain in the other cavities is less than 1 dB; under normal circumstances, one adjustment of the input power is sufficient.

IV. Computation Results and Discussion

The computational results of the overall program obtained are in two parts: one is used to check the rationality of the program in terms of physics, such as the influence of gap electron field distribution (including phase distribution) on interaction, the influence of backward waves, especially to carry out careful checking of the conservation of energy; the second part is the computation of an actual rectifier.

To check the degree of conservation of power, we defined the conservation of power coefficient α :

$$\alpha = \frac{P_{Fk} - P_0 - P_{B(k+1)} + P_{B1} + P_{beam} + P_{loss}}{V_0 I_0} \quad (28)$$

in which P_{Fk} and P_0 are the forward wave input power and the output power to k cavity; $P_{B(k+1)}$ and P_{B1} are backward wave power input to k cavity and backward wave power output from the first cavity. If k is the last cavity, $P_{B(k+1)} = 0$. P_{beam} is the kinetic energy power of the electron beam; P_{loss} is the over all loss of k cavity. If space charge is not considered in computations, within the molecules are arrayed the forward current input power of all the power and should be equivalent to the electron beam. Therefore $\alpha=1$ represents the energy's precise conservation. When space charge is considered, the space charge potential energy power should be added to the molecule to obtain conservation of energy. However, computing space charge potential power is both time-consuming and without any practical significance. Therefore, first of all Table 1 gives the results when we do not have to consider the space charge in computing. From the table we can see that before counting in backward waves, the precision of the first 10 cavities α is as high as 10^{-6} . But when the backward wave is counted in, $\alpha=0.999996$ for the tenth cavity. This error is determined by the convergence precision of backward wave iteration. This precision is high enough.

Table 2 gives the computational results of the actual circuit, and from here it can be seen that after considering the space charge the relationship of the conservation of energy is still satisfactory enough. Except for the last five cavities, a is greater than 0.99, i.e., the space charge potential energy power accounts for less than 1 percent of the total power. By the last several cavities, the bunching of the electron beams is very tight, the space charge potential energy power is increased, but it also accounts for only 1-2 percent of the total power. (30)

From the computational results above it can be seen that the model used in this paper is very rational, and computational precision is high enough. Figure 3 is a comparison of the theoretical computations and actual test results of a coupled-cavity TWT. The computation of this circuit's impedance

Table 1. Computational results when space charge not considered (input = 10W)

k	$ V_{Fk} $	G_k	P_{Fk}	P_{beam}	P_{Bk}	P_{Bi}	P_{Floss}	P_{Bloss}	a
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(a) NB = 1 Results when backward wave not considered

1	$0.108D+3$	$-0.889D-1$	$0.980D+1$	$0.783D+5$	0.0	0.0	0.0	0.0	$0.100000D+1$
2	$0.101D+3$	$-0.715D+0$	$0.848D+1$	$0.783D+5$	0.0	0.0	$0.843D+0$	0.0	$0.100000D+1$
3	$0.944D+2$	$-0.129D+1$	$0.743D+1$	$0.783D+5$	0.0	0.0	$0.157D+1$	0.0	$0.100000D+1$
4	$0.938D+2$	$-0.134D+1$	$0.734D+1$	$0.783D+5$	0.0	0.0	$0.221D+1$	0.0	$0.100000D+1$
5	$0.105D+3$	$-0.343D+0$	$0.924D+1$	$0.783D+5$	0.0	0.0	$0.284D+1$	0.0	$0.100000D+1$
6	$0.132D+3$	$0.163D+1$	$0.145D+2$	$0.783D+5$	0.0	0.0	$0.384D+1$	0.0	$0.100000D+1$
7	$0.173D+3$	$0.399D+1$	$0.251D+2$	$0.782D+5$	0.0	0.0	$0.489D+1$	0.0	$0.100000D+1$
8	$0.227D+3$	$0.633D+1$	$0.430D+2$	$0.782D+5$	0.0	0.0	$0.705D+1$	0.0	$0.100000D+1$
9	$0.292D+3$	$0.851D+1$	$0.710D+2$	$0.782D+5$	0.0	0.0	$0.107D+2$	0.0	$0.100000D+1$
10	$0.367D+3$	$0.105D+2$	$0.112D+3$	$0.781D+5$	0.0	0.0	$0.169D+2$	0.0	$0.100000D+1$

(b) NB = 5 Results at five iterations (backward wave already converged)

1	$0.108D+3$	$-0.879D-1$	$0.980D+1$	$0.783D+5$	$0.101D+0$	$0.992D-1$	0.0	$0.871D-2$	$0.100000D+1$
2	$0.101D+3$	$-0.697D+0$	$0.852D+1$	$0.783D+5$	$0.131D+0$	$0.992D-1$	$0.843D+0$	$0.200D-1$	$0.100000D+1$
3	$0.947D+2$	$-0.127D+1$	$0.747D+1$	$0.783D+5$	$0.218D+0$	$0.992D-1$	$0.158D+1$	$0.388D-1$	$0.100000D+1$
4	$0.942D+2$	$-0.131D+1$	$0.740D+1$	$0.783D+5$	$0.104D+0$	$0.992D-1$	$0.222D+1$	$0.478D-1$	$0.999999D+0$
5	$0.106D+3$	$-0.325D+0$	$0.928D+1$	$0.783D+5$	$0.519D+0$	$0.992D-1$	$0.286D+1$	$0.924D-1$	$0.999999D+0$
6	$0.132D+3$	$0.163D+1$	$0.145D+2$	$0.783D+5$	$0.474D-1$	$0.992D-1$	$0.365D+1$	$0.965D-1$	$0.999999D+0$
7	$0.173D+3$	$0.397D+1$	$0.250D+2$	$0.782D+5$	$0.104D+1$	$0.992D-1$	$0.491D+1$	$0.186D+0$	$0.999998D+0$
8	$0.226D+3$	$0.631D+1$	$0.427D+2$	$0.782D+5$	$0.876D-2$	$0.992D-1$	$0.705D+1$	$0.186D+0$	$0.999998D+0$
9	$0.291D+3$	$0.848D+1$	$0.704D+2$	$0.782D+5$	$0.177D+1$	$0.992D-1$	$0.107D+2$	$0.339D+0$	$0.999996D+0$
10	$0.366D+3$	$0.105D+2$	$0.111D+3$	$0.781D+5$	0.0	$0.992D-1$	$0.168D+2$	$0.339D+0$	$0.999996D+0$

Table 2. Actual computation results of coupled-cavity TWT

k	$ V_{Fk} $	η	G_k	P_{Fk}	P_{beam}	P_{Bk}	P_{B1}	P_{loss}	a
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(a) First segment (before attenuator)

1	$0.556D+2$	$0.141D-4$	$-0.156D+0$	$0.110D+1$	$0.764D+5$	$0.155D+1$	$0.148D+1$	$0.352D-1$	$0.100D+1$
2	$0.451D+2$	$0.923D-5$	$-0.199D+1$	$0.723D+0$	$0.764D+5$	$0.211D+1$	$0.148D+1$	$0.108D+0$	$0.100D+1$
3	$0.466D+2$	$0.988D-5$	$-0.169D+1$	$0.773D+0$	$0.764D+5$	$0.299D+1$	$0.148D+1$	$0.193D+0$	$0.100D+1$
4	$0.803D+2$	$0.293D-4$	$0.303D+1$	$0.229D+1$	$0.764D+5$	$0.150D+1$	$0.148D+1$	$0.245D+0$	$0.100D+1$
5	$0.118D+3$	$0.632D-4$	$0.637D+1$	$0.495D+1$	$0.764D+5$	$0.153D+1$	$0.148D+1$	$0.555D+0$	$0.100D+1$
6	$0.153D+3$	$0.106D-3$	$0.860D+1$	$0.828D+1$	$0.763D+5$	$0.434D+1$	$0.148D+1$	$0.212D+1$	$0.100D+1$
7	$0.185D+3$	$0.156D-3$	$0.103D+2$	$0.112D+2$	$0.763D+5$	$0.179D+1$	$0.148D+1$	$0.381D+1$	$0.100D+1$
8	$0.218D+3$	$0.215D-3$	$0.117D+2$	$0.169D+2$	$0.763D+5$	$0.533D+1$	$0.148D+1$	$0.599D+1$	$0.100D+1$
9	$0.306D+3$	$0.427D-3$	$0.147D+2$	$0.334D+2$	$0.763D+5$	$0.799D+1$	$0.148D+1$	$0.656D+1$	$0.100D+1$
10	$0.435D+3$	$0.860D-3$	$0.177D+2$	$0.673D+2$	$0.763D+5$	0.0	$0.148D+1$	$0.732D+1$	$0.100D+1$

(b) Second segment (after attenuator, output segment)

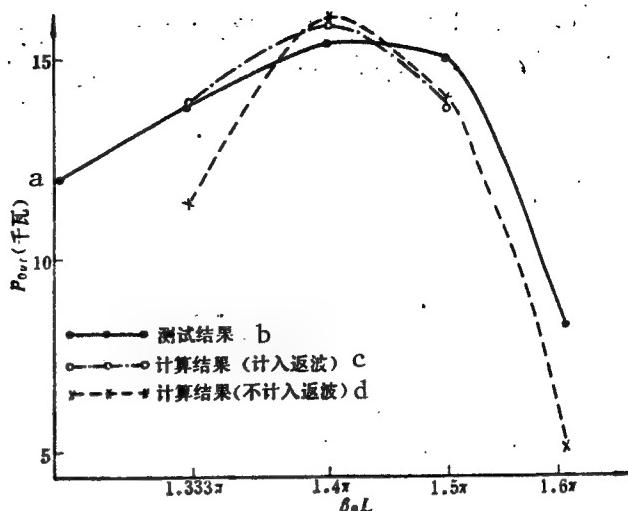
11	$0.258D+3$	$0.304D-3$	$0.132D+2$	$0.238D+2$	$0.762D+5$	$0.493D+2$	$0.148D+1$	$0.773D+2$	$0.999D+0$
12	$0.488D+3$	$0.108D-2$	$0.187D+2$	$0.846D+2$	$0.701D+5$	$0.115D+2$	$0.148D+1$	$0.797D+2$	$0.999D+0$
13	$0.849D+3$	$0.102D-2$	$0.212D+2$	$0.150D+3$	$0.781D+5$	$0.670D+2$	$0.148D+1$	$0.105D+3$	$0.999D+0$
14	$0.833D+3$	$0.316D-2$	$0.234D+2$	$0.247D+3$	$0.759D+5$	$0.354D+2$	$0.148D+1$	$0.136D+3$	$0.999D+0$
15	$0.106D+4$	$0.514D-2$	$0.255D+2$	$0.402D+3$	$0.757D+5$	$0.557D+2$	$0.148D+1$	$0.187D+3$	$0.998D+0$
16	$0.147D+4$	$0.977D-2$	$0.283D+2$	$0.764D+3$	$0.753D+5$	$0.232D+3$	$0.148D+1$	$0.294D+3$	$0.998D+0$
17	$0.201D+4$	$0.184D-1$	$0.310D+2$	$0.144D+4$	$0.742D+5$	$0.349D+2$	$0.148D+1$	$0.428D+3$	$0.996D+0$
18	$0.257D+4$	$0.302D-1$	$0.332D+2$	$0.238D+4$	$0.731D+5$	$0.209D+3$	$0.148D+1$	$0.706D+3$	$0.995D+0$
19	$0.320D+4$	$0.467D-1$	$0.351D+2$	$0.365D+4$	$0.713D+5$	$0.336D+3$	$0.148D+1$	$0.111D+4$	$0.992D+0$
20	$0.403D+4$	$0.740D-1$	$0.371D+2$	$0.579D+4$	$0.686D+5$	$0.153D+2$	$0.148D+1$	$0.119D+4$	$0.990D+0$
21	$0.447D+4$	$0.104D+0$	$0.385D+2$	$0.811D+4$	$0.665D+5$	$0.549D+3$	$0.148D+1$	$0.134D+4$	$0.988D+0$
22	$0.551D+4$	$0.138D+0$	$0.398D+2$	$0.108D+5$	$0.631D+5$	$0.224D+3$	$0.148D+1$	$0.153D+4$	$0.986D+0$
23	$0.613D+4$	$0.171D+0$	$0.407D+2$	$0.134D+5$	$0.601D+5$	$0.151D+3$	$0.148D+1$	$0.178D+4$	$0.984D+0$
24	$0.639D+4$	$0.186D+0$	$0.410D+2$	$0.145D+5$	$0.590D+5$	$0.417D+3$	$0.148D+1$	$0.200D+4$	$0.986D+0$
25	$0.624D+4$	$0.177D+0$	$0.408D+2$	$0.139D+5$	$0.590D+5$	0.0	$0.148D+1$	$0.242D+4$	$0.986D+0$

was done through a program from "large perturbation method" cold measure results. The impedance computation method is discussed in another paper. [9] The distributed decay of this circuit and the decay of the cavities were both provided through cold measure. Figure 3 also provides the computational results while both considering backward waves and not considering backward waves. From this we can see that the further $\beta_0 L$ gets from 1.5π , the greater the impact of the backward wave. The computational results and the test results basically agree, but the program has to perform more computations so that it is constantly improved. When we consider backward waves now, the computational frequency criteria are $\beta_0 L$ from 1.333π to 1.6π . When $\beta_0 L > 1.6\pi$ the gain declines very quickly, therefore before carrying out computation

Figure 3. Comparison of computed results and measured results

Key:

- a. kw
- b. measured results
- c. computed results
(including backward wave)
- d. computed results
(not including backward wave)



again, when $\beta_0 L < 1.333\pi$, there were five iterations without convergence. Because the time required for each backward wave iteration is long, it does not permit continuous computation, but when by actual measurement $\beta L < 1.333\pi$, it is still highly effective and the circuit is stable. Thus, much work still needs to be done on how to expand computation frequency band when time permits, in the iterative process for example, how to both guarantee accuracy and reduce as much as possible the multiple computations of space charge and what kind of relaxation factors to select during backward wave iteration all need further study.

Comrades Song Peide [1345 1014 1795], Wu Jingxian [0702 7234 6343], and Sun Furu [1327 4395 1172] participated in this work, and Comrades Chen Xiulan [7115 4423 1526] and Feng Songyun [7458 2646 0061] contributed much valuable test data for the computations in this article and we would like to express our thanks.

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APPLIED SCIENCES

EXPERIMENTAL FACILITY OF SHANGHAI GAS TURBINE FACTORY DETAILED

Beijing ZHONGGUO JIXIE BAO in Chinese 6 Dec 85 p 1

[Article by Lu Bo [7120 3134]]

[Text] The completely Chinese-designed and built 200-ton high-speed dynamic balance experimental facility of the Shanghai Gas Turbine Factory was certified at the Ministry level on 23 November 1985. Experts agreed that this facility has reached a standard comparable to that of similar product built by the Schenck Co of West Germany. A few days ago, experts from Sweden, the United States, West Germany were invited to tour the facility and made the following remarks after the tour: "You have designed and built a world-class dynamic balance facility." "Your success will break Schenck Co's monopoly of the world market."

The 200-ton, high-speed dynamic balance experimental facility of the Shanghai Gas Turbine Factory is one of the nuclear power engineering projects; it is an essential experimental facility for developing nuclear power generators and large thermal power generators. Under the sponsorship of the Ministry of Machine Building and the Shanghai No 1 Electromechanical Bureau, the research and design of this facility began in 1975, and the construction work took 10 years to complete. Since its completion, the facility has been used for the dynamic balance tests of 10 gas turbine rotors. The results showed that all performance indices have reached the standards of similar products made abroad. One of the dynamic balance tests involved the gas turbine rotor of a 125,000-kW generator of the Minxin Power Plant; they were very satisfied with the result. The actual cost of the facility is about 10 million yuan, which is only one-third of the cost of a similar facility imported from abroad.

This experimental facility was designed by the No 2 Design Institute of the Ministry of Machine Building. Significant contributions were also made by the Shanghai Experimental Machine Factory, the Shanghai Gas Turbine Factory, the Shanghai Electric Motor Factory, the Shanghai Design Institute of Electromechanical Products, the Shanghai No 2 Electric Meter Factory, the Shanghai Jiaotong University and the Shanghai Research Institute of Power Tools. With cooperative efforts by all participants, solutions were found to many difficult problems such as the sealing of vacuum chambers, supplying oil to bearings under vacuum conditions, deformation and sealing of the 8.5-m diameter door of the vacuum chamber.

FIRST FREE-ELECTRON LASER OPERATIONAL

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12, No 12, 20 Dec 85 p 767

[Article by Zhu Cheng [5969 2052], Lu Zaitong [7120 6528 6639], Shi Ruigen [2457 3843 2704], Wang Zhijiang [3769 0037 3068], Shi Jinchuan [2457 3160 1556], and Hu Yu [5170 3558]: "First Free-Electron Laser in China Now Operational"]

[Text] Output from China's first free-electron laser has been obtained. This free-electron laser is based on stimulated Raman scattering.

The electron beam is emitted from a retrofitted model EB-1 high current pulsed electron accelerator. The voltage is 0.5 MeV, the beam current is 50 kA, and the pulse width is 60 ns. The 6 mm diameter solid cylindrical electron beam and the 16 mm diameter, 1 mm thick hollow cylindrical electron beam both produced laser output. The electron beam enters the drift tube under the guidance of a strong axial magnetic field (0-20 kG variable) and is pumped by the static magnetic wigglers. (Both the right-handed circularly polarized double-wound electromagnetic wiggler and the axially symmetric ring-shaped permanent magnetic wiggler had laser outputs.) Under the appropriate combination of parameters, coherent spontaneous amplification of laser radiation is obtained. The radiation originates from the Ka band at the end of the drift tube and the output comes out of a horn after a gain of 13 dB. The output is received by an H-surface horn and is guided into the shielded layer by a 3.3 m long waveguide. The waveform of the radiation is recorded by a system consisting of a high pass filter, a variable attenuator, a crystal detector, and an oscilloscope. Typical experimental results are: width at half maximum = 20 ns, average power = 0.5 MW, and the wavelength is in the Ka band (8 mm or so). The output level is still one to two orders of magnitude lower than the best results obtained abroad, but the level will be improved after parameter optimization experiments. Details of the experimental setup and analysis of the experimental results will be published separately.

9698/6091
CSO: 4008/34

APPLIED SCIENCES

OPTICAL DISK MEDIA RESEARCH DISCUSSED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12, No 12, 20 Dec 85 pp 705-712

[Article by Hou Jinchun [0186 0603 2504] and Gan Fuxi [1626 4395 3588] of the Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences: "Research and Development of Optical Disk Media"]

[Text] Abstract: A review of the current status of the research and development on various optical disk media is presented. It is noted that research around the world on the media for nonerasable optical disk is almost over and nonerasable optical disk has been successfully used for CD, LD player and DRAW devices. On the other hand, great efforts are now being made to search the more suitable medium for erasable optical disks. Extensive experiments on various material systems including optical characteristic change, phase transition and magneto-optical recording media are under way. It is expected that fruitful results will appear in the next 2 or 3 years.

The new optical disk information storage technology has the advantages of high storage density (1-2 orders of magnitude greater than magnetic disk storage), rapid access, interfaceable to computer and other information system, long life (greater than 10 years) and low price per bit. The research of nonerasable optical disk material began in the mid-1960's, shortly after the debut of lasers. Today nonerasable optical disks are in the application stage and large-scale research and development of nonerasable optical disk material has gained maturity. Erasable optical disks have just been developed and the material research of erasable optical disks is being pursued actively.

The phase transformation, change of state and other property changes caused by the interaction of the laser and the material can all be used in information storage. As far as optical storage materials are concerned, the general requirements are: 1) high sensitivity to light, 2) high storage density, 3) high signal-to-noise ratio, 4) stable over long period of time, and 5) readily formed into large uniform thin films. The optical disk storage materials developed to date are mostly heat sensitive thin films that undergo phase transformation, change of state or other property changes upon absorbing the light energy. Nonerasable disks undergo nonreversible changes and erasable disks undergo reversible changes.

I. Burn-in Type Optical Disk Material

The burn-in type optical disks are one-time writing disks. The master disks of digital compact disks and videodisks currently sold on foreign markets belong to this type.

The material at the focal point absorbs laser energy and forms cavities or bubbles. The signals are recorded by these cavities or voids produced in the thermal burning process because the reflectivity of the cavities or bubbles is different from that of the surrounding medium. The general material requirements are: 1) The coefficient of absorption must be large for the wavelength used in the writing process; 2) the burning should take place at a low temperature; 3) it should be a large difference in reflectivity between the host medium and the cavities or bubbles; 4) the cavities or bubbles should be uniform and regular; and 5) the voids, bubbles and the medium should have long stability. Figure 1 shows the recording mechanisms of a single layer burn-in type optical disk. Figure 1(a) shows a simple burn-in type structure; Figure 1(b) shows the low reflectivity microscopic needle structure produced by plasma etching on thin films of silicon or germanium.¹ The bubble and blister structures in Figure 1(c) and 1(d) are produced in semiconductors containing hydrogen² and in organic emulsion.³ Figure 1(e) shows the high reflectivity RhSi alloy recording mechanism⁴ formed on a rhodium substrate by laser burning. To improve the burning action, the signal-to-noise ratio, and the stability, a number of multilayered structures have been used. The main feature is that the absorption layer and the burn-in layer are separated and that an antireflection coating and a protective coating are used.

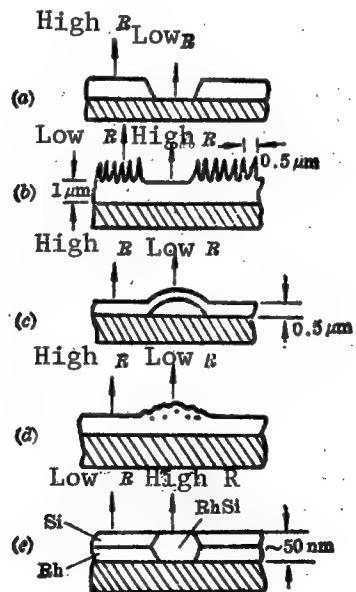


Figure 1. Single layered structures for burn-in recording

Figures 2(a) and 2(b) show the bubble formation in a two-layered and a three-layered structure. Figure 2(c) shows the most commonly used metal film sandwich structure containing a protective gas to prevent the oxidation of the metal film. More complex structures containing a reflection layer and a number of protective layers also exist (Figure 2(d)).

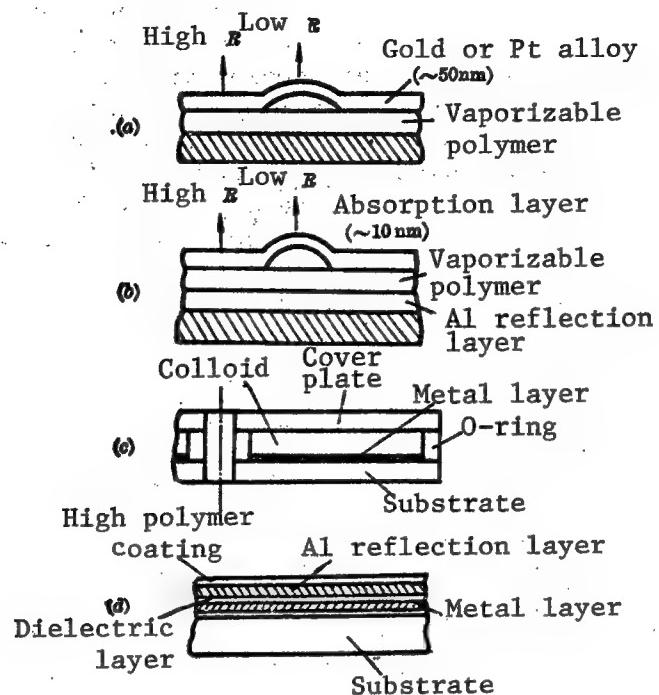


Figure 2. Multi-layered structures for burn-in recording

There is a great variety of burn-in type optical disk materials. Metal and alloy film disks are most extensively researched and developed; more than 80 percent of the nonerasable disks sold on the foreign market are metal or alloy film disks. Table 1 shows the test results of metal disk materials.⁵ Tellurium has a low melting point (450°C), a low heat conductivity (24 W/m·deg), a high absorbing ability for light, and good hole-forming properties. However, amorphous tellurium films cannot be easily formed and the grain boundaries in polycrystalline films affects the evenness of hole formation. Selenium and antimony are often added to tellurium in forming amorphous films. Common tellurium based films are Te-Bi, Te-C, and Te/Te-Se double films.⁶⁻⁸ Sulphur series compounds have also been investigated, including As-Te, Ge-Te, As-Se, Ge-Se and Sb-S. As₂₀Teg₈₀ has the best performance.⁹ The threshold of the writing laser is low, the holes are even and free of debris. The amount of debris in the hole depends on the difference in the boiling points of the two elements.

The main problem with tellurium alloy films is their chemical instability. They can be easily oxidized or damaged by electric corrosion. This is a common problem with low melting point materials. The chemical stability of the films may be improved by changing the alloy composition and raising the

melting point, but this often increases the laser power density required in the hole burning. Other approaches include applying protective coating, improving the outer coating to make it impervious to gas, and designing new multilayer or sandwich structures. Today a 30 cm optical disk can store 10^{10} - 10^{11} binary signals with a video signal-to-noise ratio greater than 60 dB, a normalized error rate of 10^{-12} , and a storage life longer than 10 years. Companies are still working on the research and development of material improvements and film manufacture technology to make them even better. Organic recording media should be given special attention. The Ricoh Company in Japan has recently explored the possibility of using organic sec-methyl dye to replace the metal film. This organic material has a low thermal conductivity and the spot size can be as small as 0.7 μm (the smallest spot size on a metal film is 0.9 μm). The storage capacity will be raised by 30 percent and the cost is only about one-third of that of metal film optical disks.¹⁰

Table 1. Melting Point, Laser Threshold for Hole Formation, and Signal-to-Noise Ratio in Read-Out of Different Metals at a Wavelength of 0.488 μm

Metal	Melting point T_m ($^{\circ}\text{C}$)	Threshold P_r (mW)	Signal-to-noise ratio (dB)
Ti	1668	12	54
Ge	937	9	38
Al	660	15	43
Te	450	3	54
Pb	327	3	36
Bi	271	3	41
In	156	5	40

II. State Transformation Optical Disk Materials

These materials are nonstoichiometric oxides. In the presence of the right reducing agent, a number of oxides form nonstoichiometric oxides (LO_x). The optical transmissibility of LO_x thin films often decreases under the action of light (Figure 3) or heat (Figure 4). This is the optical (or thermal) blackening phenomenon caused by the changes of the characteristic absorption limit. TeO_x is a suitable optical disk material¹¹ because its saturation ratio is large and it is sensitive to light (Figure 3).

Under laser radiation, the TeO_x film not only changes its transmissivity T, but also its refractive index n and its attenuation coefficient k. Along with changes in n and k, the reflectivity of the film also changes. This may be exploited to achieve the read-out purpose. As the content of Te increases, the difference in refractive index and attenuation coefficient before and after the heat treatment increases (Figure 5), the temperature of the change of state decreases (Figure 6), and the chemical stability of the material also decreases.

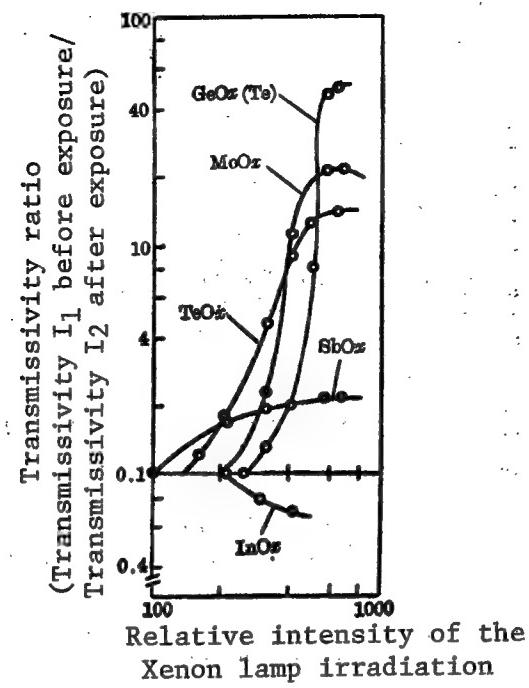


Figure 3. Changes in transmissivity of various metal oxide memory films under Xe lamp radiation

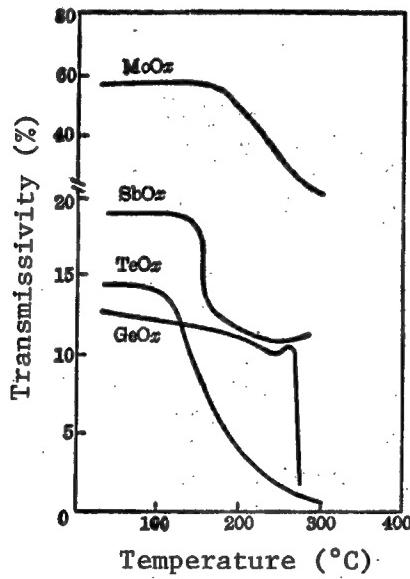


Figure 4. Transmissivity changes of oxide memory films under heating

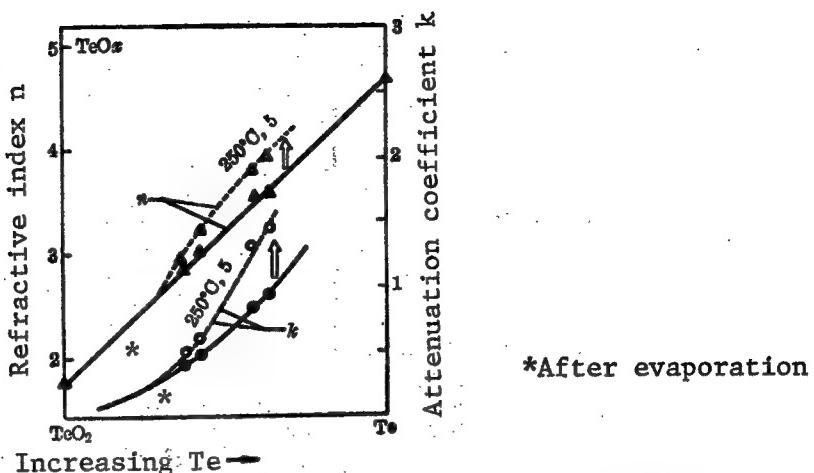


Figure 5. Refractive index and attenuation coefficient of TeO_x film as a function of Te content. Solid line: before heat treatment; Dashed line: after heat treatment

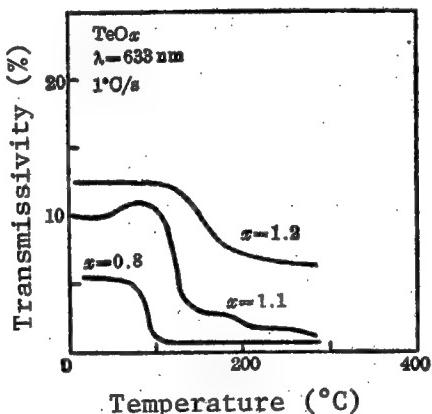


Figure 6. The blackening temperature of TeO_x film as a function of composition

Under certain laser irradiation conditions, the optical properties of TeO_x films with small amounts of added Ge and Sn become reversible and serve as the basis for erasable optical disks. $\text{TeO}_x:\text{Ge}$ 5 percent, Sn 10 percent optical disks made with a vapor method show a carrier noise ratio of 55 dB for a 5 MHz recording frequency and can be erased 10^6 times.

VO_2 show similar properties, its refractive index and optical absorption coefficient change after thermal treatment and metallic vanadium may precipitate out. Its transformation temperature is low and the change is reversible. It is reported that the properties remain unchanged after 10^8 cycles.¹²

Certain amorphous semiconductors such as sulfide glasses undergo changes in their refractive index and absorption limit under laser radiation. The absorption limit of $\text{As}_{40}\text{Se}_{50}\text{Ge}_{10}$ amorphous film moves toward longer wavelength

after it is irradiated for 2 ms by a 10 mW acousto-optically modulated He-Ne laser. After a heat treatment at 200°C, the absorption edge moves toward a shorter wavelength again. By controlling the chemical composition and heat treatment, this reversible reaction may be used in making erasable optical disks.

III. Phase Transformation Type Optical Disk Materials

This type of materials consists of the sulphur series semiconductor glass films. Their negative bulk resistance and their conductivity changes caused by electrical pulses have been utilized in the 1970's to make threshold switches and ROM's.

When an amorphous $\text{Te}_{81}\text{Ge}_{15}\text{Sb}_2\text{S}_2$ film is irradiated with an He-Cd laser ($0.44 \mu\text{m}$) or an Ar^+ laser ($0.488 \mu\text{m}$), the recording power is 10 mW, the material fuses within 2 μs , and the film becomes polycrystalline after cooling. Using a 20 mW microsecond laser pulse, the amorphous state may be restored.¹³ The crystallization temperature of a $\text{Te}_{50}\text{Ge}_{15}\text{As}_5$ film is 75–90°C; small crystallites of Te appear in the high Ge content amorphous phase and the reflectivity drops from 60 percent to 40 percent. The speed of the phase change is very rapid. For a light spot speed of 10^5 cm/s , the theoretical writing rate¹⁴ should be 200 Mbits/s. Optical disks have been made with such sulphur series compounds,¹⁵ the film thickness is 500–1500 Å. The disks are written with a GaAlAs semiconductor laser with a focusing lens of a numerical aperture of 0.4 and the writing speed is 20 linear meters per second. For an interaction time of 1 μs , and a power density of $0.3\text{--}1 \text{ mW}/\mu\text{m}^2$, melting and crystallization take place within 50 μs . The light pulse for restoring the amorphous state (erasure) is 0.1 μs long.

Recently developed phase transformation materials include Se-Te-x-y , where x is a stabilizer, usually Ge, Pb, or As, and y is a sensitizer for faster erasure, usually Ga, Sb, Sn, or Bi. Thin films made by sputtering or evaporation can provide 10^6 cycles of crystalline-amorphous transformations. A practical problem of such materials in application is the long erasure time. Even with the help of the sensitizer, the erasure time is still five times longer than the recording time.

IV. Magneto-Optic Optical Disk Materials

The writing of the magneto-optic material makes use of the Curie temperature or the compensation temperature and the reading of the magneto-optic material makes use of the Kerr effect. Table 2 lists some of the important magneto-optic storage media. The amorphous rare earth-transition metal alloys (RE-TM) developed in the mid-1970's have no crystalline boundaries and a low noise figure and their 1 μm domains are quite stable. The recording is done perpendicular to the film surface, the storage density is high, the recording sensitivity is good, the required laser power is low (a few milliwatts), and can be fabricated into large uniform films.

Table 2. Development of Magneto-Optic Storage Materials

Year	Magnetic material	Single crystal	Polycrystalline	Amorphous	Mode of storage	Major development	Company
1957	MnBi				T _c recording, observed by hot probe Kerr effect		Bell
1958					T _c recording, using electron beam		
1960					Laser recording proposed	He-Ne laser	IBM
1965	Gd ₃ Fe ₅ O ₁₂ (bulk)				T _{com} recording proposed	Semiconductor laser	
1968			EuO MnBi		High density read and write testing, using gas laser	Magnetic bubble storage	IBM
1972	Gd ₃ Fe ₅ O ₁₂ (film)		CoP(NiFe) MnAlGe			Optical disk	
1973	(GdYb) ₅ Al ₁₅ O ₁₂		MnGaGe	GdCo	Using gas laser in reflection mode	Vertical recording	
1975		CrO ₂	TbFe		Using gas laser,	Laser videodisk	NTT NHK
		MnTbB ₁	DyFe,		magneto-optic disk		
		PtCo	TbCo				
			GdFe				
1978	(TbYb) ₃ (FeGa) ₅ O ₁₂ (SmEr) ₃ (GaFe) ₅ O ₁₂		YGdFe GdFeBi GdTbFe		Semiconductor laser, optical disk storage	Laser compact disk (audio), high density magnetic disk	

The RE-TM alloys may be made into amorphous films by sputtering or by evaporation, the components are shown in Figure 7. The film is magnetized during or after its formation and the magnetic flux lines are perpendicular to the film surface. Under a focused laser, the temperature at the recording point exceeds the Curie temperature or the compensation temperature. In the presence of a magnetizing field, the flux at the recording point reverses and forms a domain, as shown in Figure 8.

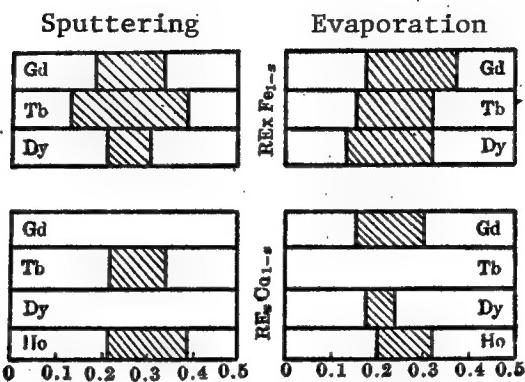


Figure 7. Amorphous RE-TM alloys

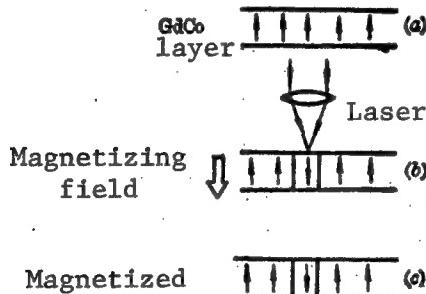


Figure 8. Recording on a magneto-optic thin film

In order to increase the recording density, the film must be magnetized vertically. The condition for a vertical magnetization is:

$$K_u > 4\pi M_s$$

where K_u is the vertical magnetization anisotropy constant, and M_s is the saturation magnetization. The stability of the recording point is:

$$4\pi M_s \left| \frac{l}{2d} - \frac{1}{1+3d/2h} \right| < H_0$$

with H_c being the coercive force, d being the diameter of the recording spot, l being the characteristic length of the medium and equal to $\sigma_w/4\pi M_s$, where σ_w is the domain wall energy density, and h is the film thickness. When $d \gg h$, the minimum diameter for a stable domain is:

$$d = \sigma_w/2M_s H_c$$

From a storage density and stability standpoint, the material should have as large as K_u and H_o as possible.⁵

The read-out of the signal makes use of the polarized Kerr rotation effect. When a linearly polarized incident light impinges on the film surface normally, the polarization direction of the reflected light is rotated. The elliptically polarized light is first decomposed into linearly polarized light and the two beams are then received in a differential mode. The received signal intensity is then proportional to the Kerr rotation angle and the signal-to-noise ratio is:

$$S/N \propto \sqrt{R} Q_k$$

where R is the reflectivity of the film and Q_k is the Kerr rotation angle. To improve the S/N, the material should have a large Q_k .

Amorphous RE-TM films are obtained by rapid quenching. Thermodynamically the film is in a metastable state and it will crystallize when the temperature is raised. Amorphous materials also undergo a structural relaxation process with a relaxation activation energy of only 0.5 eV. In addition, domain instability may be induced by structural changes and external conditions. When RE-TM films are in contact with oxygen, selective oxidation may occur. The rare earth elements tend to oxidize first and change the film property. In order to have long-term stability, the optical disk material should have thermodynamic, magnetic, and chemical stability.

The rare earth-transition metal alloys may be divided into two classes: the iron series and the cobalt series. The iron series alloys, such as TbFe and DyFe, can be easily made into amorphous films by sputtering or evaporation. Their Curie temperature used for recording does not change with composition greatly (see Figure 9); as a result, compositional inhomogeneities do not affect the film property greatly. The disadvantages of the iron series films are the low level of stability and the small Kerr rotation angle.¹⁶ The cobalt series materials, such as GdCo and DyCo, make use of the compensation temperature in recording. Because of the larger change of the coercive force with temperature (shown in Figure 10), the recording sensitivity is high, the writing temperature is low and stable, and the thermal stability of the material is better than that of the iron series. But because of the large change of the compensation temperature with composition, uniform thin films are hard to make and small recording dots are not stable enough.

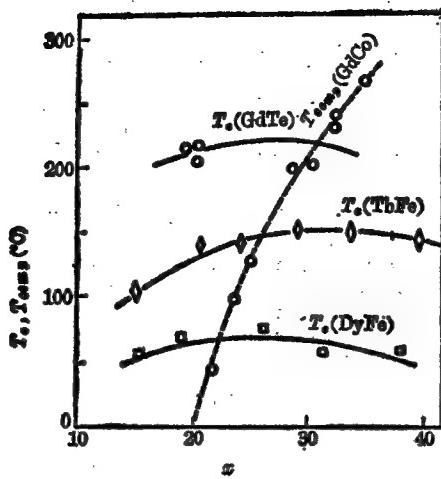


Figure 9. Curie temperature (T_c) of $RE_xFe(100-X)$ and compensation temperature (T_{comp}) of $RE_xCo(100-X)$ as a function of composition

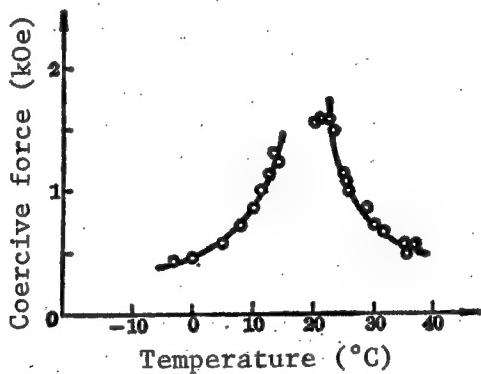


Figure 10. H_c of GdCo as a function of temperature

The Kerr rotation angle of Fe and Co series binary amorphous films is usually 0.3-0.35 degrees. Ternary, quaternary, and pentac amorphous films are currently being studied in the search for a greater Kerr rotation angle. Ternary films usually have a Kerr angle of 0.4 degrees or so. The $(Gd_{50}Tb_{50})_y(Fe_{65}Co_{35})_{1-y}$ quaternary hybrid Fe-Co optical disks¹⁷ with a rotation angle of 0.45-0.5 degrees made their debut in May 1984. Experiments are under way at Osaka University to add a fifth element Sm in GdTbFeCo quaternary material.

In addition RE-TM amorphous films, other amorphous and polycrystalline magnetic materials have also been investigated. Recently polycrystalline PtMnSb alloys¹⁵ are found to have a Kerr rotation of 1.27 degrees at 720 nm and 0.77 degrees at 830 nm, the largest rotation angles to date. Unfortunately, no large area uniform films are yet available. Table 3 shows the properties of various magneto-optic materials.

Table 3. Properties of Magneto-Optic Materials

Material	Amorphous films						Polycrystalline films		
	GdCo	GdFe	TbFe	TbFe-Co	GdTb-Fe	GdFe-Bi	Pt-MnSb	Mn-CuBi	Mn-AlGe
Recording temp (°C)	120 (T_{comp} ²⁰)	210	140	200	160	145	210	210	245
Kerr rotation (deg)	0.33	0.85	0.8	0.4	0.4	0.41	0.77	0.43	0.1
Wavelength (nm)	633	633	633	633	830	633	830	830	633

To overcome the chemical instability of RE-TM films (mainly the preferential oxidation of the rare earth elements), researchers have investigated other oxide systems including stoichiometric and nonstoichiometric of rare earth or transition metal oxides, and some iron oxides and garnets.

The oxygen atmosphere is carefully controlled in the film fabrication process to avoid oxidation. Films are usually made in an oil-free vacuum chamber. A transparent protective layer is often added to the RE-TM film to keep the film from getting in contact with oxygen. Most magneto-optic disks are coated with SiO₂. It was discovered recently that oxygen has entered the RE-TM film in the SiO₂ sputtering process and affected the long-term stability of the film. As an improvement, the Central Research Institute of the Sharp Company used AlN film¹⁸ instead of SiO₂ film.

The value of Q_k in single layer RE-TM films is usually small (0.2–0.4 degrees). This may be enhanced by having a multilayer structure. An anti-reflection film is first laid down to reduce surface reflection losses, a metal film is then placed at the bottom to improve the light energy conversion, finally a thin interference film is used to enhance the output signal.¹⁰ Figure 11 shows the multilayer structure, and Table 4 shows the calculated parameters. Experiments using MnBi films showed that the signal-to-noise ratio of a four-layer film is almost twice that of a single film.²⁰

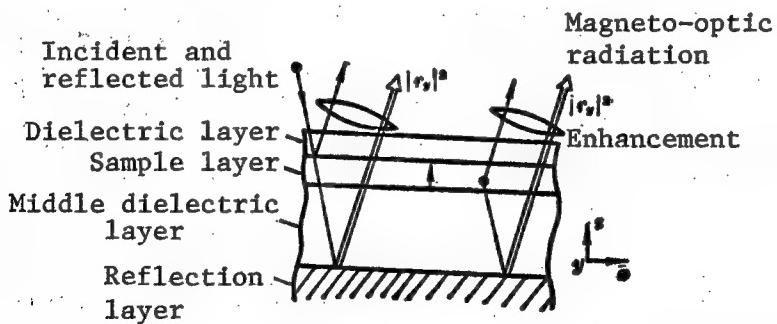


Figure 11. Multilayer magneto-optic film structure

Table 4. Calculated Parameters of Multilayer Magneto-Optic Films

No	Medium layer			
	1	2	3	4
1	—	RE-TM Thick	SiO ₂ Thick	—
2	SiO ₂ (1200 Å)	RE-TM Thick	SiO ₂ Thick	—
3	SiO ₂ (1200 Å)	RE-TM (1800 Å)	SiO ₂ (1100 Å)	Al Thick

No	Reflec-tivity	Kerr rota-tion Q _K	Ellipti-city	Kerr intensity r _y ² × 10 ⁴
1	0.60	0.45	0.22	0.47
2	0.34	1.00	0.54	1.37
3	1.84	1.84	3.24	8.00

A great effort is being made by the Electronics Technology Institute of the Japan Industrial Technology Institute to develop composite magneto-optic films. The composite film is a two-layer RE-TM amorphous film: a TbFe film coated with a GdCo or GdTbCoFe film. The composite film has the superior magnetic properties of the TbFe film such as the high coercive force H_C and the convenient Curie temperature T_C (150°C), and also a large Kerr rotation angle (0.5° or so) comparable to that of a GdTbFeCo film and 2-3 times greater than that of a TbFe film.²¹

Read and write optical disks made of amorphous magneto-optic materials have already been developed in recent years. Table 5 lists the technical parameters of various optical disk materials.

From the analysis above, one can see that the nonerasable optical disks today are mostly the burn-in type multilayer alloy films, although gas bubble type organic gel and dye materials are also under development. Erasable optical disks are still in the research stage. In addition to the phase transformation, change of state, and magneto-optical disks under study, photochromatic, electrochromatic and photovoltaic materials are also being explored. New ideas of optical disk storage media continue to appear and better nonerasable and erasable materials are expected in the development of the optical disk technology.

Table 5. Technical Parameters of Magneto-Optic Disk Components

Company	KDD	Sharp	Matsushita	NIKK	NTT	NHK	Sony	Xerox	Philips
Parameter									
Recording medium	TbFe/ GdTbFe T_c	TbDyFe/ GdTbFe T_c	MnCuBi/ GdTbFe T_c	GdCo	MnBi/ MnCuBi T_c	CrO ₂	γ Fe ₂ O	TbFe	GdTbFe T_c
Recording method	140/160	70/150	200/160	Tcomp	T_c	H_c	H_c	T_c	T_c
Operating temperature (°C)	0.3/0.4	0.5/0.7	0.43/0.4	0.3	0.7/0.2	RIG-1	RIG	--	--
Kerr rotation angle (deg.)	120/200	140	120	150	135	300	250	76.2	50.8
Disk diameter (mm)									
Substrate material	Glass/ organic glass	Glass	Glass	Glass	Glass	Thin plate	Glass	PMMA	
Rotational speed (rpm)	450-1800	720	400	1800	1000- 2000	1800	360	1200	600
Light source	GaAlAs	GaAlAs	GaAlAs	He-Ne	Ar	Ar	Magnetic head	LD	LD
Recording power (mW)	5-10	4.5	5	5.6	40-70	30-60	--	4.9	3
Reconstruction light source	GaAlAs	GaAlAs	GaAlAs	He-Ne	Ar	He-Ne	He-Ne	LD	LD
Reconstruction power (mW)	1-2.7	~2	~2	~2	10-25	~10	5.6	--	1
Dimension (μm)	1	1	1	1	2	2x7	5x20	1	2
Channel gap (μm)	2.5	2	5	3-6	5	15	200	2	10
Input/output signal	Digital	Digital	Digital	FM	Digital	FM	FM	--	--
Write-read speed (MHz)	0.5-2	2	2	1-5	0.5	10	1-3	--	--
S/N, C/N (dB)	C/N-45 $\sim 10^{-5}$	C/N-40 --	C/N-40 --	C/N>35 --	S/N-40 6.28x 10 ⁻⁶	S/N~ --	S/N-37 --	S/N-37 --	S/N-30 --
Error rate									

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9698/6091
CSO: 4008/34

APPLIED SCIENCES

CORNEA INJURY BY CO₂ LASER STUDIED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12, No 12, 20 Dec 85 pp 739-741

[Article by Xu Jiemin [1776 4309 2404], Zhou Shuying [0719 3219 5391], Hu Fugen [5170 1381 2704], Cao Weiqun [2580 4850 5028], Xu Guidao [1776 6311 6670], Qian Huanwen [6929 3562 2429], Wang Denglong [3769 4098 7893], and Shi Liangshun [2457 5328 7311] of the Institute of Radiation Medicine, Academy of Military Medical Sciences: "Injury Threshold of Cornea by CO₂ Laser Light Exposure"]

[Text] Abstract: The minimal visible lesion in the corneal epithelium resulted from exposure to CO₂ laser light has been carefully determined. The dose to cause 50% damage probability (ED₅₀) varied with time of exposure: for 1.03 s was 5.72 W/cm² (95% CL 5.8-5.85 W/cm²) and for 0.12 s was 10.7 W/cm² (95% CL 10.4-10.9 W/cm²).

CO₂ lasers are widely used in industry, scientific research, medical care and military. In this article we studied the occurrence frequency cornea injury as a function of exposure time and level of irradiation and obtained the injury threshold.

I. Experiment

Figures 1 and 2 depict the experimental irradiation setup. The apparatus consists of a CO₂ laser, a power attenuator, a timing control, a transmission type power monitor, a collimating He-Ne laser, a finite aperture, and an animal irradiation table. The maximum output power is 20 W, the output stability is ± 3 percent, the output is an approximate single transverse mode, and the divergence angle is less than 2.5 mrad.



Figure 1. Exposure device

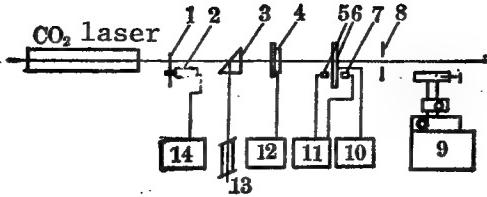


Figure 2. Light path of the exposure device

- | | |
|-----------------------------|------------------------|
| 1. Stainless steel screen | 8. Diaphragm |
| 2. D.C. motor | 9. Animal table |
| 3. Right angle prism | 10. Timer control |
| 4. Transmission power meter | 11. Timer |
| 5. Light source | 12. 1503 digital meter |
| 6. Shutter | 13. He-Ne laser |
| 7. Photoelectric tube | 14. Power supply |

The exposure time is measured to an accuracy of 0.5 percent or better. Two groups of exposure times with averages of 1.03 s and 0.12 s, respectively, are used. The standard deviations in time measurement are less than ± 1 percent and ± 5 percent, respectively. The standard deviation in power measurement is less than ± 5 percent.

Experimental animals are gray rabbits weighing 2.4-3.7 kg. The corneas are found to be normal in microscopic examinations before the irradiation. The rabbit is placed on a frame with three degrees of freedom and a 1 mm diameter diaphragm is placed in front of the eye to confine the laser beam. Alignment is achieved with an He-Ne laser along the same optical path. Examinations are made with a crevasse lamp and a microscope within 10 minutes after the exposure. Some of the eyeballs are removed for pathological examination. A total of 854 exposure spots on 142 rabbit eyes are made in 11 groups. The average exposure time is 1.03 seconds for the first six groups and 0.12 seconds for the remaining five groups.

II. Results

1. The damages caused by the average power density of $4.17\text{-}13.4 \text{ W/cm}^2$ used in our tests are all superficial minor injuries confined to the top layer of the cornea. Circular gray or light gray injury spots were observed. Light injuries showed as light gray points or crescent spots with a white point in the middle. Most of the injury spots disappeared within 16-24 hours after the exposure. Gray injury spots faded considerably after 48-72 hours.
2. The cornea injuries were studied as a function of exposure dose and exposure time. Two exposure times were used and the injury results for 11 sets of tests are given in Table 1. As can be seen, the frequency for cornea injury increases with the average power density. For the same level of injury, the power density decreases as the exposure time increases.

Table 1. CO₂ Laser Exposure Dose, Time and Cornea Injury Frequency

Test No.	Average exposure time (sec)	Dosage		Injury frequency	
		Average energy density (J/cm ²)	Average power density (W/cm ²)	Injury/sample points	Percent
1	1.0463	8.32	7.95	50/50	100
2	1.0251	7.07	6.89	61/66	92.4
3	1.0240	6.62	6.47	70/82	85.4
4	1.0233	6.04	5.90	25/50	50.0
5	1.0215	5.50	5.39	26/72	36.1
6	1.0232	4.27	4.17	2/102	1.96
7	0.1209	1.62	13.4	62/70	88.6
8	0.1218	1.45	12.0	47/60	78.3
9	0.1211	1.31	10.9	34/60	56.7
10	0.1219	1.24	10.1	68/192	35.4
11	0.1280	0.972	7.59	4/50	8.0

3. Cornea injury threshold calculation: The cornea injury threshold ED₅₀ for CO₂ laser usually refers to the exposure dosage for 50 percent probability observable injury within 10 minutes after the exposure. Experimental results show that, for an exposure time of 1.03 seconds, the regression equation is:

$$\hat{Y} = 16.86x - 7.611$$

$$ED_{50} \approx 5.72 \text{ W/cm}^2$$

(95 percent confidence level is 5.58-5.85 W/cm²)

For an average exposure time of 0.12 seconds, the regression equation is:

$$\hat{Y} = 11.77x - 7.087$$

$$ED_{50} \approx 10.7 \text{ W/cm}^2$$

(95 percent confidence level is 10.4-10.9 W/cm²)

III. Pathological and Histological Observation of Injuries

Physiopathological and histological observations of 23 rabbit eyes show that, for the radiation level used in this study, the injuries of the cornea are coagulation of the three focal regions:

1. Central necrosis region: At the center of the burned cornea, cell coagulate leads to necrosis and local epithelium detachment. This injury may vary in size and location, but occurs mostly at the center of the affected region. It may also occur to one side of the center, possibly due to the variation of the "hot spot" of the CO₂ laser. In serious cases, the entire epithelium is detached and a flat bottom or conical pit is formed. In lighter injuries the epithelium cells flake off and leave islands. The substrate layer shows no observable changes.

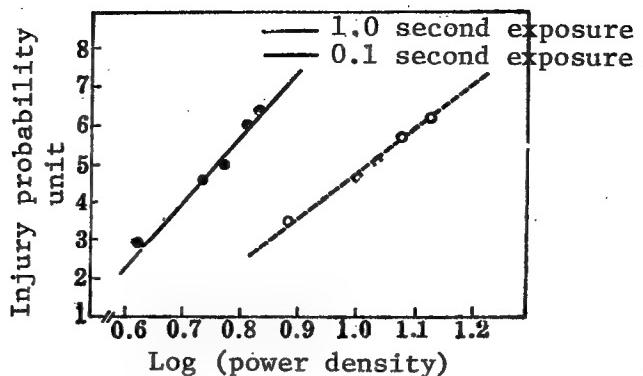


Figure 3. CO₂ laser exposure dose, exposure time, and frequency of cornea injury. Solid line: 1.035 seconds, dashed line: 0.125 seconds.

2. Surrounding coagulation region: The level of injury decreases as the light intensity decreases toward the surrounding. Injuries of the region surrounding the necrosis are mostly cell coagulation and shrinkage, decoloration and fragmentation of the nuclei are observed.

3. Peripheral edema and coagulation region: At the peripheral of the focal region the flat or wing-shaped cells of the shallow epithelium layer show swelling or coagulation and nuclear wrinkling is observed.

The degree of injury varies with the irradiation dosage. Severe injuries are associated with large area of damage and extensive necrosis. Light injuries show no necrosis and only epithelium coagulation, as shown in Figure 4. Very slight injuries are small and shallow and extend only to the shallow layer of cells. Some focal regions have the appearance of a disk with a diameter of 200-300 μm . Injuries occurring at the threshold level are mostly light or very light.



Figure 4. Cornea epithelium cell damage caused by CO₂ laser

The authors thank Tang Zhongming [3828 0112 2494] for his assistance in statistical data analysis using a computer.

9698/6091
CSO: 4008/34

LASER PULSE COMPRESSOR AND PHASE-COMPENSATOR DESCRIBED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12, No 12, 20 Dec 85 pp 750-751

[Article by Wu Cunkai [0702 1317 1956], Lan Guang [5663 0342], Xu Jie [1776 2212], and He Guozheng [0149 0948 3791]: "Laser System With Pulse-Compressor and Phase-Compensator"]

[Text] In the development of nonlinear phase conjugate optics, a number of phase conjugate cavity¹ and phase conjugate mirrors² have been proposed for the phase anomaly in the laser amplifier. In Ref. 3 a composite laser system with a stimulated Brillouin scattering (SBS) conjugate mirror was studied and 200 mJ of output was obtained using a polarization isolation technique. In Ref. 4, pulse compression was observed using the usual capillary Brillouin cell and using a ruby laser as a pump. In Ref. 5, higher order pulse compression was achieved with a long conical capillary Brillouin cell. In this work, we combined the composite laser system in Ref. 3 and the conical capillary Brillouin scattering conjugate mirror. Using a polarization isolation method, the compressed laser pulse is completely coupled out. Using a 670 mm tapered capillary Brillouin cell containing CS₂ liquid, the pulse width of the Q-switched Nd:YAG laser amplifier in the composite system is compressed by a factor of 3. The laser pulse energy is more than 240 mJ. The degree of compression depends on the length of the capillary; by changing the length of the Brillouin cell, it is possible that a variable pulse width laser can be made.

Figure 1 shows the composite laser system. The total reflection mirror M₁ and the coated glass plate M₀ constitute the Nd:YAG oscillator cavity. An irradiated LiF crystal is used as the Q-switch. The Q-switched output pulse has a full width at half maximum of 30 ns.

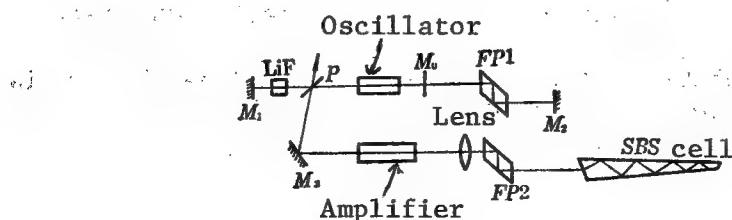
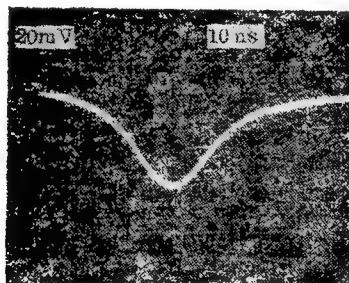
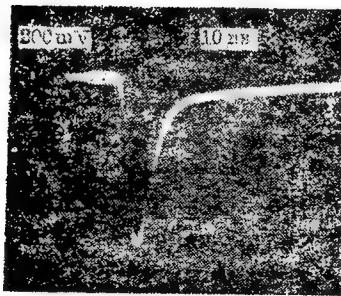


Figure 1. A composite laser system with a conical capillary SBS conjugate mirror

A polarizer P is inserted into the cavity as a coupler. The polarizer reflects all the S-component and transmits all the P-component. The oscillator output goes through the Fresnel prism FP1 and turns into a circularly polarized light. It then reflects from M_2 and passes through FP1 one more time and becomes an S-polarized light. The light is amplified by the laser medium of the oscillator, reflected by the polarizer P into the Nd:YAG amplifier, focused by the long focal length lens, and turned into a circularly polarized light by another Fresnel prism FP2 before it enters the 670 mm conical capillary. The incident diameter of the capillary is 8 mm and the exit diameter is 1.5 mm. The capillary is filled with a CS_2 liquid. Since CS_2 has a large refractive index ($n = 1.63$), the light beam propagates in the capillary by total internal reflection. Because the SBS conjugate mirror does not have a polarization inversion, the back scattered light remains circularly polarized but the sense of rotation is opposite to that of the incident circularly polarized light. As a result, when the back wave passes through FP2 again, it becomes a light of P-polarization. This conjugate wave goes through the amplifier medium for a second time, the phase anomaly of the medium is compensated and the output is coupled out by the polarizer P. The energy of the laser pulse entering the Brillouin cell is about 240 mJ. For a focal length of 1.3 m, the output energy of the composite laser system is about 160 mJ. The output energy can be easily varied by changing the focal length of the lens. At a focal length of 800 mm, the output is 230 mJ or so. Figure 2(a) shows the input laser pulse waveform of the Brillouin conjugate mirror, the full width at half maximum is about 30 ns. Figure 2(b) shows the output waveform of the composite system, the full width at half maximum is about 10 ns. The pulse width compression factor is 3.



(a)



(b)

Figure 2. (a) Incident wave of the conical Brillouin scattering cell
 (b) Output wave of the composite laser system

Using a regular SBS cell, a backward wave cannot be obtained by a lens with a focal length greater than 500 mm under our experimental conditions. The conical Brillouin cell not only compresses the pulse width but also allows the use of longer focal length lens due to the compression of the light beam in the capillary tube. This has prevented damages of the Brillouin cell, an important practical consideration. Furthermore, the present system can deliver several tens of millijoules of backward wave even without the help of a focusing lens.

Figure 3 shows the near-field and far-field patterns of the composite laser system. The divergence of the output is better than 2×10^{-3} rad. The divergence angle of a laser without phase compensation is about 3×10^{-3} rad.

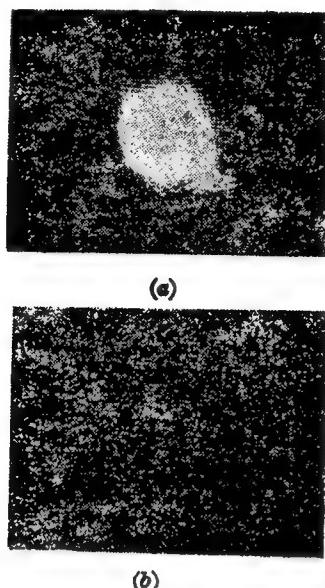


Figure 3. (a) Near-field and (b) far-field pattern of the composite laser output

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9698/6091
CSO: 4008/34

APPLIED SCIENCES

STANDING WAVE WIGGLERS USED IN FREE-ELECTRON LASER

Shanghai HONGWAI YANJIU [CHINESE JOURNAL OF INFRARED RESEARCH] in Chinese
Vol 4, No 5, Oct 85 pp 374-378

[Article by Lei Shizhan [7191 0099 3277]: "A Free-Electron Laser with Standing Wave for Wigglers"]

[Text] Abstract: Operating condition for free-electron lasers with standing wave for wigglers are analyzed and the laser gains are calculated.

I. Introduction

A unique feature of free electron lasers is that the output wavelength can be tuned continuously by changing the energy of the relativistic electrons and the spatial period of wiggler. In principle, output can be obtained in the infrared, ultraviolet, and even the X-ray range. The wavelength of the laser is¹

$$\lambda_r = \frac{\lambda_w(1+K^2)^{-1}}{2\gamma^2}, \quad (1)$$

where K is a constant determined by the wiggler parameters, γ is a relativistic factor equal to the ratio of the electron energy and mass m_0c^2 , and λ_w is the spatial period of the wiggler. As can be seen, a high energy relativistic electron beam is required to produce short wavelength laser. Recently attempts have been made to obtain laser oscillation in the X-ray wavelength² using free electron laser but great technical difficulties were encountered.

Another approach to obtain short wavelength radiation is to shorten the period λ_w of the wiggler. For example, if the spatial period of the wiggler of a 54 MeV relativistic electron beam is $10\mu m$, then the radiation wavelength of the free electron laser will be in the X-ray range. However, it is exceedingly difficult to construct a wiggler with a period in the micrometers using conventional static magnetic or electric fields. In this paper we propose that microwave or laser radiation standing waves be used as a wiggler to achieve a spatial period of micrometers or even shorter.

II. Basic Equations

Suppose a wiggler is established by standing wave radiation in the z direction with a wavelength λ_w , the magnetic field B_w and electric field E_w of the wiggler

$$B_w = B_w [\hat{x} e^{-(k_w z + \varphi_w)} - i \hat{y} e^{-(k_w z + \varphi_w)}] + \text{c. c.}, \quad (2)$$

$$E_w = E_w [\hat{x} e^{i(k_w z + \varphi_w)} - i \hat{y} e^{i(k_w z + \varphi_w)}] + \text{c. c.} \quad (3)$$

are respectively where B_w and E_w are the standing wave amplitudes, $k_w = 2\pi/\lambda_w$, φ_w is the initial phase, and \hat{x} and \hat{y} are unit vectors in the transverse direction.

If the lateral linewidth of the relativistic electron beam is small enough, the lateral variation of the wiggler field and the radiation field can be neglected and the vector potential A_w of the wiggler may be written as

$$A_w = [A_w e^{-(k_w z + \varphi_w)} + A_w e^{i(k_w z + \varphi_w)}] \hat{e} + \text{c. c.}, \quad (4)$$

where A_w is the amplitude of the wiggler field and $\hat{e} = \hat{x} - i \hat{y}$. The radiation field vector potential A_r may be written as

$$A_r = [A_r e^{(k_r z - \omega_r t + \varphi_r)} + A_r e^{-(k_r z - \omega_r t + \varphi_r)}] \hat{e} + \text{c. c.}, \quad (5)$$

where A_r is the amplitude of the vector potential A_r , $k_r = 2\pi/\lambda_r$, λ_r is the wavelength of the radiation field, ω_r is the circular frequency of the radiation field, and φ_r is the initial phase of the radiation field.

The Hamiltonian of the relativistic electron is

$$H = c[(P - eA)^2 + m_0 c^2]^{\frac{1}{2}} - \gamma m_0 c^2, \quad (6)$$

where P is the eign momentum of the relativistic electron, m_0 is the rest mass of the electron, and c is the speed of light. The equation of motion of the Hamiltonian operator is

$$\left. \begin{aligned} p_i &= -\frac{\partial H}{\partial q_i}, \\ q_i &= \frac{\partial H}{\partial p_i}. \end{aligned} \right\} \quad (7)$$

where p_i are the three components of the eign momentum of the relativistic electron and q_i are the three position coordinates. Substituting (3) and (4) into (5), we find from (7) that

$$\dot{p}_x = -\frac{\partial H}{\partial x} = 0,$$

$$\dot{p}_y = -\frac{\partial H}{\partial y} = 0.$$

That is, the transverse eign momentum is a constant and is determined by the initial conditions. If the electrons enter the wiggler with a zero transverse velocity ($v_{\perp} = 0$), then the constant may be taken to be zero of $\vec{P}_{\perp} = 0$. This shows that the dynamic transverse momentum of the electron is

$$P_{\perp} = -eA = m_0 c \gamma \beta_{\perp}, \quad (8)$$

where $\beta_{\perp} = \frac{v_{\perp}}{c}$. From (8), we obtain the transverse velocity unit vector:

$$\beta_{\perp} = -\frac{eA}{m_0 c \gamma}. \quad (9)$$

The motion of the electron in the wiggler is described by the Lorentz equation of motion:

$$\frac{d\gamma}{dt} = -\frac{e}{m_0 c} \beta \cdot E, \quad (10)$$

$$\frac{d}{dt}(\gamma\beta) = -\frac{e}{m_0 c} [E + c\beta \times B]. \quad (11)$$

from (10) and (11), we have

$$\frac{d}{dt}(\gamma\beta_z) = \frac{d}{dt}\gamma, \quad (12)$$

where β_z is the z component of $\vec{\beta}$. Upon integrating (12), we have

$$\gamma(1-\beta_z) = \gamma_0(1-\beta_{z0}), \quad (13)$$

where γ_0 is the relativistic factor of the electron entering the wiggler, $\gamma_0 = (1-\beta_{z0})^{-\frac{1}{2}}$; $\beta_{z0} = v_{z0}/c$, v_{z0} is the longitudinal velocity of the electron upon entering the wiggler.

From (10), we have

$$\frac{d\gamma}{dt} = -\frac{e}{m_0 c} \beta_1 \cdot E_1. \quad (14)$$

By substituting (9) into (14), we have

$$\frac{d\gamma}{dt} = \frac{e^2 \gamma}{m_0 c^2 \gamma} A_r E_r [\sin \theta + \cos \theta]. \quad (15)$$

Substituting (4) and (5) into (15), we have

$$\frac{d\gamma}{dt} = \frac{e^2 \gamma}{m_0 c^2 \gamma} A_r E_r [\sin \theta + \cos \theta]. \quad (16)$$

where $\theta = (k_r - k_s)z + \omega_r t + \varphi_B - \varphi_0$

Equation (16) shows that the energy of the relativistic electron is not a constant even at the resonance frequency (i.e. $\omega_r = \omega_0$) and that is different from the case of a spatially periodic static magnetic field wiggler. Taking the time derivative of θ , we have

$$\dot{\theta} = (k_r - k_s)c\beta_z + \omega_r. \quad (17)$$

Therefore, the relativistic electrons emit radiation as long as the longitudinal velocity v_z satisfies the condition

$$v_z < \frac{c(\omega_r + \omega_s)}{\omega_r},$$

and the phase between the electron motion and the vector potential satisfies $\frac{\pi}{4} < \theta < \frac{5\pi}{4}$. The radiation power is a maximum when the phase $\theta = \frac{3\pi}{4}$.

The electrons are accelerated by the wiggler field when $\frac{5\pi}{4} < \theta < 2\pi$ or $0 < \theta < \frac{\pi}{4}$. At $\theta = \frac{7}{4}\pi$, the electrons absorb the maximum amount of energy from the wiggler field, when $\theta = \frac{\pi}{4}$ or $\theta = \frac{5}{4}\pi$ the electrons do not emit radiation and do not absorb energy from the wiggler field, the energy of the electron remains a constant.

III. Results and Discussion

Since the electron energy in the wiggler do not change very much, the relative factor γ may be written as

$$\gamma = \gamma_0 + \delta\gamma_1 + \delta\gamma_2 + \dots, \quad (18)$$

where $\delta\gamma_1, \delta\gamma_2 \dots$ are respectively first order small quantity, second order small quantity and so forth. From (13), the longitudinal velocity vector β_z may be approximately written as

$$\beta_z = 1 - \frac{\gamma_0}{\gamma} (1 - \beta_{z0}) + \frac{\delta\gamma_1}{\gamma_0} (1 - \beta_{z0}) + \beta_{z0}. \quad (19)$$

In order to find the gain of the free electron laser, we first find the first order small quantity $\delta\gamma_1$. From (16) we have

$$\delta\dot{\gamma}_1 = \frac{e^2}{\gamma_0 m_0 c^2} A_r E_r [\sin(\theta_0 + \theta'_0) + \cos(\theta_0 + \theta'_0)], \quad (20)$$

$$\theta_0 = [(k_w - k_r) \omega \beta_{z0} + \omega_r] t,$$

where

$$\theta'_0 = \varphi_B - \varphi_{r0}$$

By integrating (20), we have

$$\delta\gamma_1 = \frac{e^2 A_r E_r}{(k_w - k_r) \omega \beta_{z0} + \omega_r} [\sin \theta_0 - \cos \theta_0 - \sin \theta'_0 + \cos \theta'_0]. \quad (21)$$

since θ'_0 may assume any value, the average value of $\delta\gamma_1$ from 0 to 2π gives $\langle \delta\gamma_1 \rangle = 0$. The second order small quantity $\delta\gamma_2$ is therefore needed in finding the gain of a free-electron laser. From (16), we have

$$\gamma_0 \delta\dot{\gamma}_2 = \frac{e^2}{m_0 c^2} A_r E_r [\sin(\theta_0 + \theta'_0 + \delta\theta_0) + \cos(\theta_0 + \theta'_0 + \delta\theta_0)] - \gamma_0 \delta\dot{\gamma}_1, \quad (22)$$

$$\delta\theta_0 = \frac{(k_w - k_r) \omega (1 - \beta_{z0}) \delta\gamma}{\gamma_0} t,$$

where

Using trigonometric expansions of $\sin(\theta_0 + \theta'_0 + \delta\theta_0)$ and $\cos(\theta_0 + \theta'_0 + \delta\theta_0)$, and keeping in mind that $\theta_0 \gg \delta\theta_0$, we have

$$\begin{aligned} \sin(\theta_0 + \theta'_0 + \delta\theta_0) &= \delta\theta_0 \cos(\theta_0 + \theta'_0) + \sin(\theta_0 + \theta'_0), \\ \cos(\theta_0 + \theta'_0 + \delta\theta_0) &= \cos(\theta_0 + \theta'_0) - \delta\theta_0 \sin(\theta_0 + \theta'_0). \end{aligned} \quad \} \quad (23)$$

Substituting (20) and (21) into (22), making use of (23), integrating with respect to time t , and finding the average of θ'_0 in the $0 \sim 2\pi$ range, we have

$$\begin{aligned} \langle \delta\gamma_2 \rangle &= \langle \cos[(k_w - k_r) \omega \beta_{z0} + \omega_r] t \\ &\quad + [(k_w - k_r) \omega \beta_{z0} + \omega_r] t \sin[(k_w - k_r) \omega \beta_{z0} + \omega_r] t - 1 \rangle. \end{aligned} \quad (24)$$

Here

$$\mathcal{A} = \left(\frac{e^2 A_0 E_r}{m_0 c^2 \gamma_0} \right)^2 \frac{(k_w - k_r) c (1 - \beta_{s0})}{[(k_w - k_r) c \beta_{s0} + \omega_r]^2}. \quad (25)$$

Let $\psi = [(k_w - k_r) c \beta_{s0} + \omega_r] t$, (24) simplified to

$$\langle \delta \gamma_s \rangle = \mathcal{A} [\cos \psi + \psi \sin \psi - 1]. \quad (26)$$

The radiation energy of a free-electron laser comes from the energy of the relativistic electrons. If the flux of the electron beam is n_e , the radiation flux I_r of the free-electron laser will be

$$I_r = -4\gamma m_0 c^2 n_e = -\langle \delta \gamma_s \rangle m_0 c^2 n_e. \quad (27)$$

Substituting (26) into (27), we obtain the parametric relationship of the radiation flux density of the free-electron laser and the wiggler:

$$I_r = -\mathcal{A} [\cos \psi + \psi \sin \psi - 1] m_0 c^2 n_e. \quad (28)$$

The incident flux density I_0 is

$$I_0 = \frac{c}{4\pi} E_0^2. \quad (29)$$

Using (28) and (29), we obtain the gain coefficient of the free-electron laser using a standing wave wiggler:

$$G = -\mathcal{A} 4\pi m_0 n_e [\cos \psi + \psi \sin \psi - 1]. \quad (30)$$

At the zero of time, $\psi \ll 1$, and (30) gives

$$G = -4\pi m_0 c \mathcal{A} n_e t^2 [(k_w - k_r) c \beta_{s0} + \omega_r]^2. \quad (31)$$

Equation (31) shows that in the beginning stage the gain coefficient G is proportional to the square of time t . Also, to obtain a positive gain one must satisfy one of the following inequalities:

$$\begin{aligned} & k_r > k_w \\ \text{or} \quad & \lambda_w > \lambda_{r0} \end{aligned}$$

Finding the average gain under such conditions for a phase range of 0 to $\pi/2$, we have

$$\bar{G}_{0-\frac{\pi}{2}} = -4(4-\pi)m_0 n_e \mathcal{A}. \quad (32)$$

Over the range of $\pi/2$ to π , the average gain is

$$\bar{G}_{\frac{\pi}{2}-\pi} = -8m_0 n_e \mathcal{A} \left(1 + \frac{\pi}{2}\right). \quad (33)$$

For $\psi = \pi$ to $3\pi/2$, we have

$$\bar{G}_{\pi-\frac{3\pi}{2}} = -8m_0 n_e \mathcal{A} \left(2 - \frac{\pi}{2}\right). \quad (34)$$

For $\psi = 3/2\pi$ to 2π , we have

$$\bar{G}_{\frac{3}{2}\pi} - 4m_0\alpha \omega (5\pi - 4). \quad (35)$$

Equations (32) through (35) show that the condition for a gain in the $\psi = 0 \rightarrow \pi$ range is

$$\lambda_w > \lambda_r,$$

and the condition for a gain in the $\psi = \pi \rightarrow 2\pi$ range is

$$\lambda_w < \lambda_r.$$

Generally speaking, $\lambda_w > \lambda_r$ is easy to satisfy and $\lambda_w < \lambda_r$ is not. The operating condition should therefore be chosen in the $\psi = 0 \rightarrow \pi$ range. For a given wiggler field and electron beam, this condition is equivalent to requiring the light pulse duration satisfying.

$$t < \frac{\pi}{k_w c \beta_{w0} + (1 - \beta_{w0}) \omega_r}. \quad (36)$$

Equation (36) shows that the pump time must be shorter for short radiation wavelength. The situation is similar to the emission of laser by the atoms; for a short wavelength the lifetime of the energy level must be short, the pumping pulse should be short and the pumping power must be high.

Finally we estimate the laser gain for a given set of operating conditions. We choose a standing wave spatial period λ_w of 1 mm, a radiation power density of 1 kW/cm², a relativistic electron beam with $\gamma = 100$, a electron beam current density of 10 A/cm², and an incident light radiation power density of 10⁴ kW/cm². Based on Eq (1), such a wiggler and relativistic electron beam may amplify a radiation of wavelength 5000 Å. The average gain obtained from Eq (30) is 0.5/cm, comparable to that obtained from a free-electron laser with a conventional static magnetic field wiggler.

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9698/12232

CSO: 4008/30

$^{14}\text{CO}_2$ ISOTOPE LASER DESCRIBED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12 No 9,
20 Sep 85 pp 524-527

[Article by Fei Lin [6316 2651], Wang Kejun [3769 0344 0193] and Zhu Xuhui
[6175 2485 6540]: "A $^{14}\text{CO}_2 - ^{12}\text{CO}_2$ Isotope Laser"]

[Text] Abstract: A $^{14}\text{CO}_2 - ^{12}\text{CO}_2$ isotope laser has been developed and 80 laser lines were measured. Forty lines originated from lasing transition of $00^{\circ}1-(10^{\circ}0, 02^{\circ}0)$, band of $^{14}\text{CO}_2$, and the strongest line output power was over 4.0 W. The competition effect between isotopes were experimentally observed and domination of lasing radiation of $^{14}\text{CO}_2$ was found even when the content of $^{14}\text{CO}_2$ was less than $^{12}\text{CO}_2$.

I. Introduction

The CO_2 laser was invented by C.K.N. Patel in 1964¹ and the first CO_2 isotope laser was developed by I. Wieder and G.B. McCurdy^{2,3} in 1966 using $^{12}\text{C}^{18}\text{O}_2$. The $^{13}\text{CO}_2$ and $^{14}\text{CO}_2$ lasers were subsequently developed respectively by G.B. Jacobs and H.C. Bowers⁴ and J.C. Siddoway.⁵ Extensive calculations and measurements have been made on the transition spectral lines of pure isotope CO_2 lasers. In this article we present a study of the $^{14}\text{CO}_2-^{12}\text{CO}_2$ laser.

II. Experimental Setup

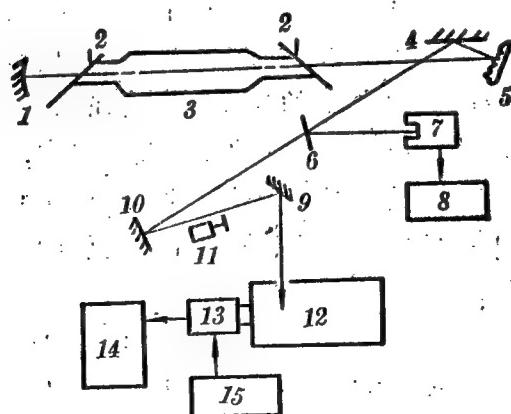


Fig. 1. Experimental Setup

[description on following page]

1. Gold plated total reflection mirror, R = 3m or 5m; 2. NaCl crystal Brewster window; 3. Quartz discharge tube; 4. Aluminum plated planar reflecting mirror; 5. Planar grating; 6. Aluminum plated planar reflecting mirror (installed while measuring laser power); 7. Carbon; 8. Power monitor; 9, 10. Aluminum plated plane mirrors; 11. Chopper; 12. Infrared grating spectrometer; 13. Thermoelectric detector; 14. Oscilloscope, and 15. DC regulated power supply

The experimental setup is shown schematically in Figure 1. The apparatus includes a 1-meter-long water-cooled quartz tube with an inner diameter of 10 mm and a discharge zone 85 cm long. The two ends are NaCl Brewster windows. The apparatus has an external cavity structure. One end has a gold plated total reflection mirror with a radius of curvature of 3 m or 5m, the other end has a planar diffraction grating and the laser output makes use of the zeroth order coupling. The 80 line/mm metal grating has a wavelength of 11 μm , the 75 line/mm grating has a wavelength of 10 μm , and the cavity length is 173 cm. The laser output goes through a chopper and an aluminum planar reflecting mirror and is projected onto an infrared spectrometer with a resolution of 0.25 cm^{-1} . The relative intensity of the laser spectral lines is measured with a RO-L thermoelectric infrared detector. The laser power is measured with a powermeter. The abundance of the radioactive $^{14}\text{CO}_2$ gas used in the experiment is about 60 percent and is provided by the Atomic Energy Institute of the Chinese Academy of Sciences. A special gas mixer vacuum system is used to blend the $^{14}\text{CO}_2$ and $^{12}\text{CO}_2$ gas with N_2 and He. The $^{14}\text{CO}_2$ gas is recovered with liquid nitrogen cooling and the residual gas is handled with a cold trap containing NaOH.

III. Results and Discussion

1. Measurement of spectral lines

The experimental conditions are current I = 8 mA, discharge voltage = 16.5 kV, total pressure in the cavity = 18.7 ± 0.2 Torr, and $\text{CO}_2:\text{N}_2:\text{He}=1:1:4.2$, $^{14}\text{CO}_2:\text{CO}_2 = 60\%:40\%$. Using an 80 line/mm metal grating, we observed 40 spectral lines of the P branch [P(4) ~ P(42)] and the R branch [R(4) ~ R(42)] of the $00^01-(10^00,02^00)$ _I band (hereafter the I band for short), including the P(4) line with $\bar{\nu}=862.97 \text{ cm}^{-1}$. To our knowledge this line has not been observed before and the wavenumber is in good agreement with the calculated values of Freed et al of the Lincoln Laboratory in the United States. In addition we have also observed 22 spectral lines in the P branch [P(10) ~ P(34)] and the R branch [R(12) ~ R(28)] of the I band. Table 1 shows the spectral lines measured with the $^{14}\text{CO}_2$ laser and the values measured by Freed et al using a beat method. As can be seen, the agreement is good. The output powers of the P(20) and R(20) lines of $^{14}\text{CO}_2$ are above 4.0 W and can still be made higher.

When a 75 line/mm metal grating is used for frequency selection, we observed 17 lines in the P branch [P(12) ~ P(30)] and the R branch [R(12) ~ R(24)] of the $^{12}\text{CO}_2$ $00^01-(10^00,02^00)$ _{II} band, and the R(10) line of the $^{12}\text{CO}_2$ I band. Since the grating has a wavelength of 10 μm , it is not in favor of the $^{14}\text{CO}_2$ oscillation and the number of $^{14}\text{CO}_2$ spectral lines is less. Also, because of

the decrease in the zeroth order coupling output of the grating, the laser output powers of $^{12}\text{CO}_2$ and $^{14}\text{CO}_2$ are reduced substantially. However, the spectral line intensities of the $^{14}\text{CO}_2$ laser are still greater than the corresponding lines of the $^{12}\text{CO}_2$ laser.

In our experiment we have never observed the $^{14}\text{CO}_2$ laser transition in the $00^01-(10^00,02^00)$ II band. This indicates that the gain coefficient of this band is too small, consistent with the conclusion in Ref. 7. Table 2 lists the small signal gain coefficients of pure isotopes given in Ref. 7. As can be seen, the gain of the $^{14}\text{CO}_2$ $00^01-(10^00,02^00)$ II band is very small. The main reason for the small gain coefficient is that the Fermi resonance plays a dominating role.⁸

2. Isotope competition effect

Figure 2 shows that there are more spectral lines in the $^{14}\text{CO}_2$ I band and the line intensities are greater than the spectral lines in the $^{12}\text{CO}_2$ band. When the ratio of $^{14}\text{CO}_2$ and $^{12}\text{CO}_2$ is changed, we find that even when the content of $^{14}\text{CO}_2$ is reduced from 60 percent to 40 percent and the grating wavelength is 10 μm (unfavorable for the $^{14}\text{CO}_2$ laser oscillation), the output spectral lines of $^{14}\text{CO}_2$ still do not change very much and the laser radiation remains dominating. For example, the output power of the R(20) line in the $^{14}\text{CO}_2$ I band is still three times greater than that of the R(20) output of $^{12}\text{CO}_2$.

Table 1 shows that when $^{12}\text{CO}_2$ and $^{14}\text{CO}_2$ exist alone, the small signal gain of P(20) in the $^{12}\text{CO}_2$ I band is about twice the small signal gain of the $^{14}\text{CO}_2$ spectrum. When the gas is a mixture of $^{14}\text{CO}_2$ and $^{12}\text{CO}_2$, however, the experimental observation shows that the reverse is true.

We believe that this is the result of an isotope competition effect. Similar effects have been observed in a $^{12}\text{CO}_2$ - $^{13}\text{CO}_2$ isotope laser by Green et al.⁹ Their interpretation also applies to our case.

The probability for resonance energy exchange between the two isotopes of CO_2 is very high,^{10,11} and there is a strong coupling between them. When the higher energy level (00^01) of $^{14}\text{CO}_2$ and $^{12}\text{CO}_2$ each undergoes population inversion, a Boltzmann equilibrium is quickly reached between the isotope molecules of the higher energy level. Since the vibrational energy of the higher energy level of the $^{14}\text{CO}_2$ laser is lower⁵ than that of the $^{12}\text{CO}_2$ laser by about 123 cm^{-1} , the Boltzmann distribution becomes even more favorable for the upper energy level of the $^{14}\text{CO}_2$ laser.

In addition, the CO_2 molecule will dissociate in the discharge:



The CO isotope molecules formed in the dissociate will also exchange energy with the CO_2 molecules. Based on the energy levels of the CO_2 molecule obtained by J. Siddoway,⁵ the energy of the first excited vibrational state of the CO isotope molecule obtained by E. Player et al.,¹² and the molecular vibrational

energy calculations made by Herzberg, we estimated that the vibrational energies of ^{12}CO ($v = 1$) and ^{14}CO ($v = 1$) are lower than the vibrational energies of $^{14}\text{CO}_2$ (00^01) by 83 cm^{-1} and 172 cm^{-1} respectively,¹² and lower² than the $^{12}\text{CO}_2$ (00^01) vibrational energy by 206 cm^{-1} and 295 cm^{-1} respectively. As shown in Figure 3, the vibrational states of ^{12}CO and ^{14}CO are closer to the vibrational state of $^{14}\text{CO}_2$, making it more favorable to the population distribution of the upper energy state of the $^{14}\text{CO}_2$ laser. The final result is that the laser radiative transition of $^{14}\text{CO}_2$ dominates the $^{14}\text{CO}_2$ - $^{12}\text{CO}_2$ isotope laser.

Table 1. Laser Spectral Lines of $^{14}\text{CO}_2$

00 ⁰¹ -[10 ⁰⁰ , 02 ⁰⁰]I					
R branch			P branch		
LINE	Measur ed ± 0.25 [cm $^{-1}$]	Ref. ^[6]	LINE	Measur ed ± 0.25 [cm $^{-1}$]	Ref. ^[6]
4	869.96	869.69	4	862.97	862.99*
6	871.44	871.47	6	861.42	861.40
8	873.04	871.96	8	859.78	859.79
10	874.32	874.43	10	858.14	858.16
12	875.81	875.88	12	856.52	856.52
14	877.32	877.32	14	854.79	854.86
16	878.61	878.74	16	853.18	853.18
18	880.35	880.15	18	851.58	851.48
20	881.55	881.54	20	849.78	849.78
22	882.86	882.91	22	848.00	848.06
24	884.28	884.27	24	846.32	846.32
26	885.60	885.61	26	844.55	844.56
28	886.93	886.93	28	842.80	842.79
30	888.26	888.23	30	841.05	841.00
32	889.59	889.52	32	839.21	839.20
34	890.93	890.79	34	837.39	837.37
36	892.17	892.04	36	835.57	835.54
38	893.40	893.28	38	833.67	833.68
40	894.65	894.50	40	831.88	831.81
42	895.78	895.70	42	830.00	829.93

* Calculated value

Table 2

Band	Small signal gain	$^{12}\text{CO}_2$	$^{13}\text{CO}_2$	$^{14}\text{CO}_2$
I	$\alpha_0 (\text{cm}^{-1})$	1.07	0.64	0.55
II	$\alpha_0 (\text{cm}^{-1})$	0.9	0.26	0.099
Measured	$\frac{\alpha_0 - \text{I}}{\alpha_0 - \text{II}}$	1.2	2.5	5.6

I Relative intensity

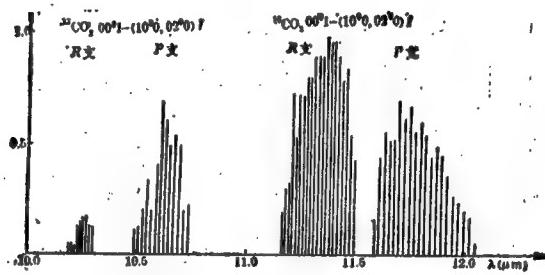
图2 $^{14}\text{CO}_2$ - $^{12}\text{CO}_2$ 同位素激光器的谱线分布

Fig. 2 Spectral distribution of the $^{14}\text{CO}_2$ - $^{12}\text{CO}_2$ isotope laser $I = 8 \text{ mA}$, $\text{CO}_2:\text{N}_2:\text{He} = 1:1:4.2$, total gas pressure = $18.2 \pm 0.2 \text{ Torr}$, $^{14}\text{CO}_2:^{12}\text{CO}_2 = 60\%:40\%$, gold plated reflection mirror $R = 3\text{m}$, 80 line/mm metal grating, $\lambda = 11 \mu\text{m}$.

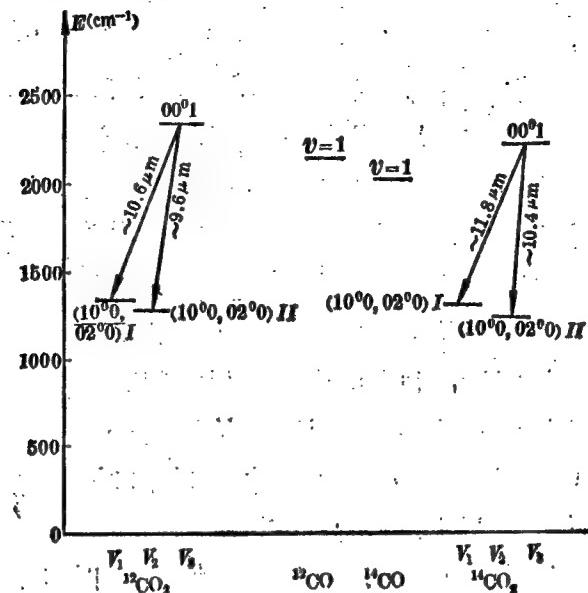


Fig. 3 Vibrational Energy Levels of CO_2 Isotope

IV. Conclusion

We have developed a tunable $^{14}\text{CO}_2$ - $^{12}\text{CO}_2$ isotope laser and extended the usual spectrum range of a $^{12}\text{CO}_2$ laser from $9-11 \mu\text{m}$ to $9-12 \mu\text{m}$.

The existence of the isotope competition effect allowed us to realize that the hybrid CO_2 isotope laser not only has a greater spectral output range than pure CO_2 isotope lasers but also saves the expensive $^{14}\text{CO}_2$ and $^{12}\text{CO}_2$ isotopes. More spectral lines may be obtained if a mixture of $^{14}\text{CO}_2$, $^{13}\text{CO}_2$, and $^{12}\text{CO}_2$ in an increasing proportion is used.

The authors thank Wu Yingju [0702 2503 5468], Lu Shanhua [0712 0810 5478], and Liang Mingqing [2733 2494 3237] for technical assistance.

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CSO: 8111/0461

AUTO-ALIGNMENT DEVELOPED FOR LARGE LASER SYSTEM

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12 No 9, Sep 85 pp 543-546, 542

[Article by Wang Wucheng [3769 2745 2052], Wang Jianxiong [3769 0494 7160], Wu Hengxian [0702 1854 7359], Guo Ruojun [6753 5387 7467], Yang Jingxin [2799 6975 2450] and Hu Shiyuan [5170 1102 0337]: "Auto-Alignment of the Optical Path of a Larger Laser System"]

[Text] Abstract: A principle of optical path adjustment by servo-control mechanism is proposed. A computer program based on this principle has been successfully used in the auto-alignment of a laser system.

Introduction

A large laser system usually consists of an oscillator, a number of amplifiers and extensive optics. While in operation it is difficult to keep the laser beam from drifting. For example, the optical path of the pulsed solid state laser system used in nuclear fusion relies on an alignment control system so that the axial and angular drifts of the beams remain within a tolerable range. In this article we report our research results in this area.

Alignment-Control System

The alignment of the laser beam is carried out in sections. Each section uses a spatial filter as the alignment standard. The angle and axial position of the main beam upon entering the spatial filter are monitored by a transducer. The transducer consists of an aiming and an orienting optical image system and two corresponding quadrant tubes. They respond respectively to the axial drift and the angular drift of the beam. When the optical axis of the target beam deviates angularly from the optical axis of the transducer, the orientation quadrant tube of the transducer will become unbalanced and produce an orientation error signal. When the optical axis of the target beam is displaced laterally from that of the transducer, the aiming quadrant tube of the transducer will produce an aiming error signal. Based on the sign and magnitude of the error

signals, the microcomputer connected to the quadrant tubes computes the angular and lateral deviation of the target beam and sends commands to the stepper motors of the two servo adjustment frames to move in the required direction by the proper number of motor steps.

The main components of the alignment control system are: two servo adjustment mechanisms with two degrees of controls for the azimuth and the pitch, a plane mirror that samples part of the target beam for the transducer, a transducer, an amplifier and a microcomputer. The layout is shown in Figure 1.

To analyze the operation of the alignment system, we consider a deviation of the optical path shown in Figure 2. The light spot positions of the aiming quadrant and the orientation quadrant of the transducer are shown in Figure 2(b). To restore the spots to their balanced positions on the quadrant tubes, the two servo mechanisms I and II should be adjusted so that the light beam AN_0 coincides with the original beam BO_0 . Servo I should be rotated counter-clockwise to move point A toward point B. Servo II is then driven counter-clockwise so that the two beams coincide. In the adjustment process, when the servo I is rotated counter-clockwise to a certain angle, CA will become parallel to DB and AN_0 is then parallel to BO_0 . This will balance the orientation quadrant tube, see Figure 3. Conversely, if servo I is rotated clockwise,

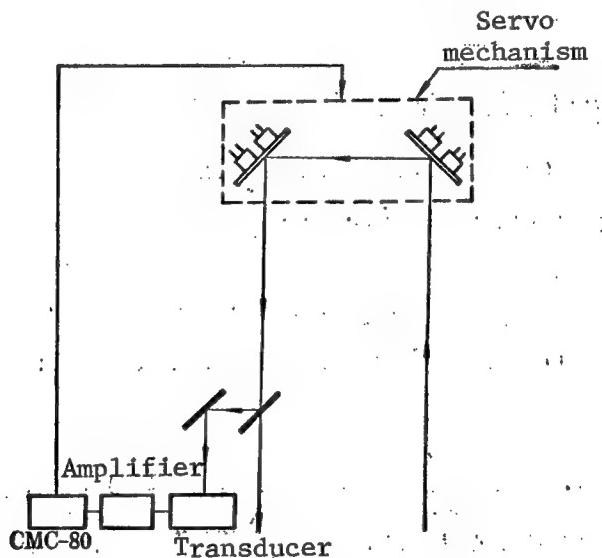


Fig. 1 Layout of the CMC-80 Auto-alignment System

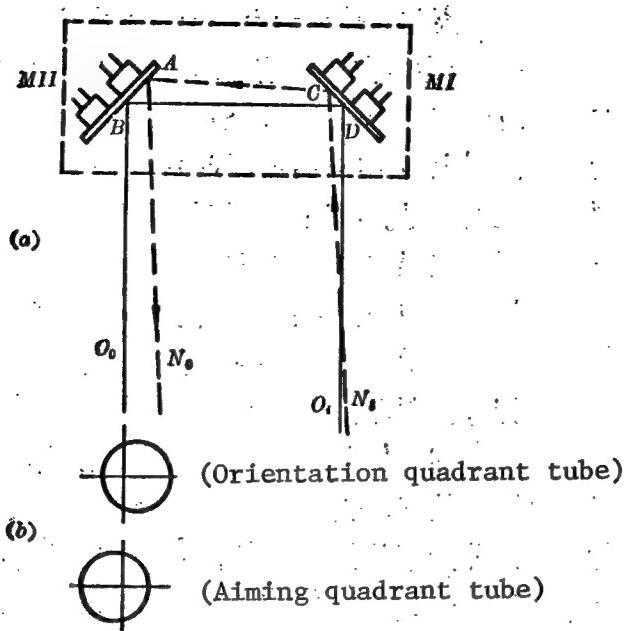


Fig. 2 Deviation of the Laser Beam

point A will increasingly deviate from point B and the orientation quadrant tube will become more and more unbalanced. The signal from the orientation quadrant tube can, therefore, be used in determining the proper rotation direction of the servo I mechanism. The angle of rotation is determined by the angular deviation of the beam upon entering servo I, that is, the angular drift of the system beam.

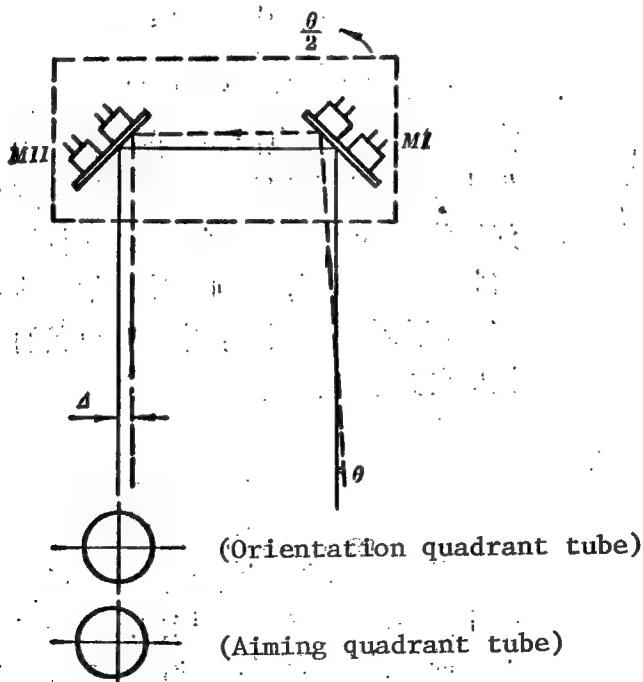


Fig. 3 Beam Orientation After $\theta/2$ Adjustment by Servo I

For an angular deviation of θ , from the well-known law of reflection, servo I should be rotated in the counter-clockwise direction by an angle $\theta/2$ so that CA and AN_o become respectively parallel to DB and BO_o, as shown in Figure 3. When the servo I is rotated an additional angle of $\psi/2$ in the same direction, point A will be brought to coincide with point B. Figure 4 shows that $\ell = \Delta/l$, where Δ is the axial deviation of the beam and l is the center-to-center distance of the mirrors of servo I and servo II. At this time the angle between the beam from servo II and the undeviated beam is also ψ . Therefore, the beam will coincide with the original undeviated beam when servo II is rotated by an angle $\psi/2$ in the same direction (counter-clockwise) as servo I. In other words, once the orientation motor rotation direction of servo I is determined and the angle is rotated to balance the orientation quadrant tube, the motor of servo II may be driven in the same direction until both quadrant tubes are balanced, see Figure 5. As can be seen, the rotational angles of servos I and II depend on the axial drift of the beam.

Based on the above, the servo adjustment concept may be summarized as follows:

- (1) Determine the correct rotational direction of the stepper motor

The proper sense of rotation of servo I is determined by the indication of the orientation quadrant tube. If the trend is toward a balance after a certain number of steps, the rotation is in the right direction. Otherwise, the sense of rotation should be reversed.

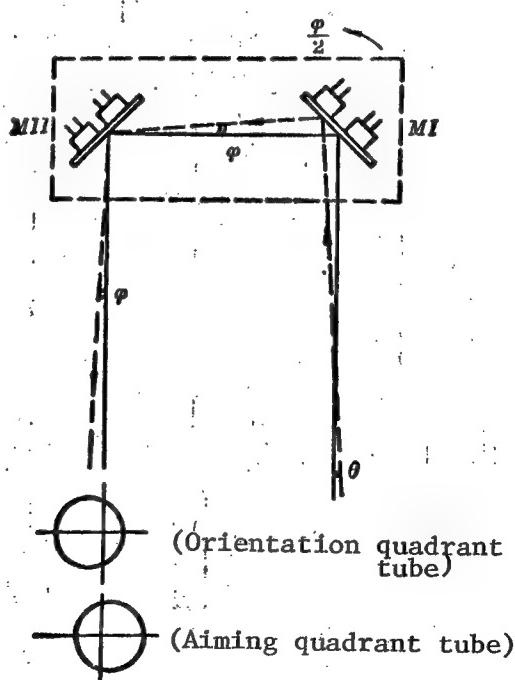


Fig. 4 Beam Orientation After Servo I Is Rotated by an Additional $\psi/2$

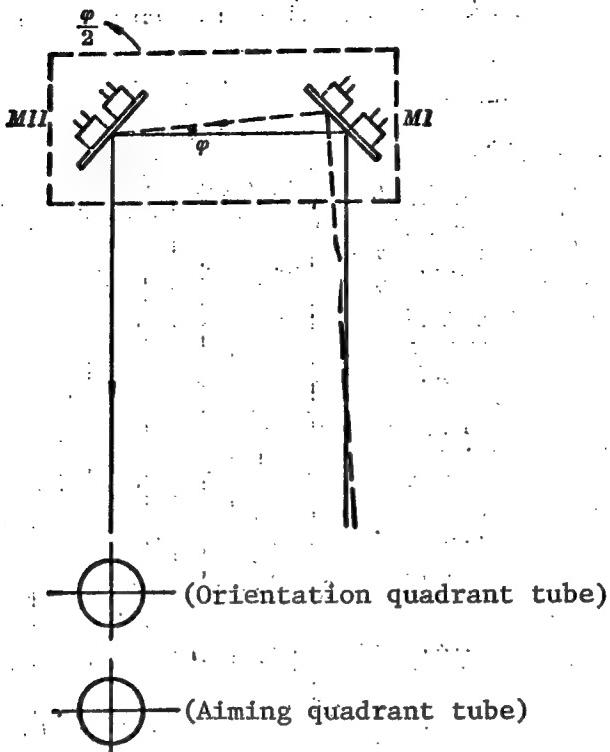


Fig. 5 Beam Orientation After Servo II Is Rotated by $\frac{\varphi}{2}$

(2) Determine the number of steps of the orientation stepper motor in servo I

Based on the direction of rotation determined above, the orientation motor of servo I is rotated until the orientation quadrant tube of the transducer is balanced. The number of steps depends solely on the angular drift of the beam.

(3) Aiming adjustment

Servos I and II are driven simultaneously in the direction determined earlier until the aiming quadrant and the orientation quadrant of the transducer are both balanced. The number of steps of the synchronized rotation of I and II depends on the axial drift of the beam.

At this point, the alignment is completed. The alignment of the pitch of the beam is similar to the alignment of the azimuth. If both have deviation, they may be corrected independently.

Computer Program

A CMC-80 computer is programmed to control the azimuth and the pitch tilt stepper motors of servos I and II. The flow diagram for azimuth-pitch control is given in Figure 6.

Experimental Results

A CW YAG laser is used as the light source in the auto-alignment experiment. The laser light is reflected from mirror M_0 and enters servos I and II. The beam is then taken out by a beam splitter and fed into the transducer. The electrical signals from the aiming and the orientation quadrant tubes are amplified by two amplifiers and fed into the CMC-80 computer. The experimental setup is shown in Figure 7.

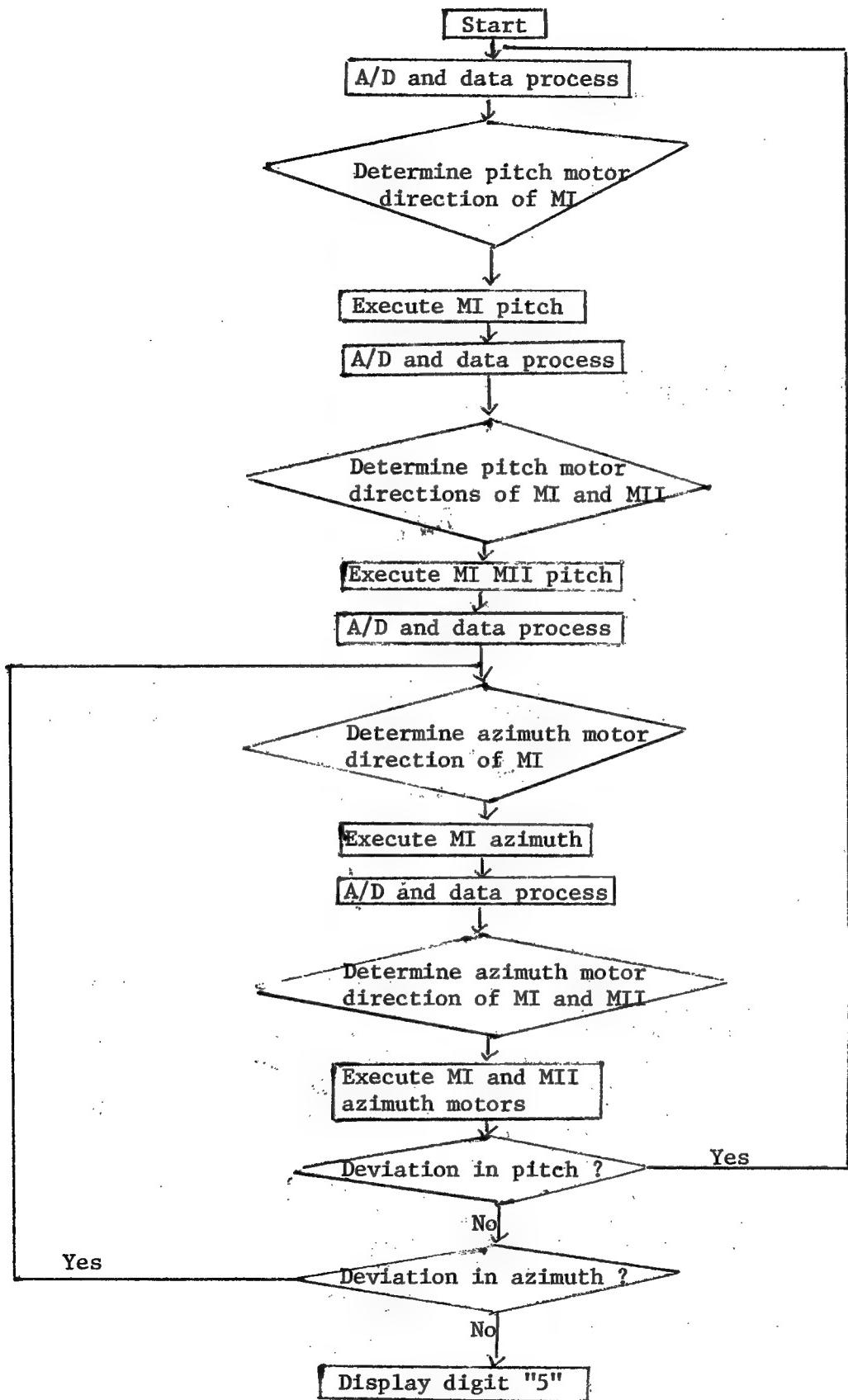


Fig. 6. Flow diagram of pitch-azimuth control of the CMC-80 based auto-alignment system

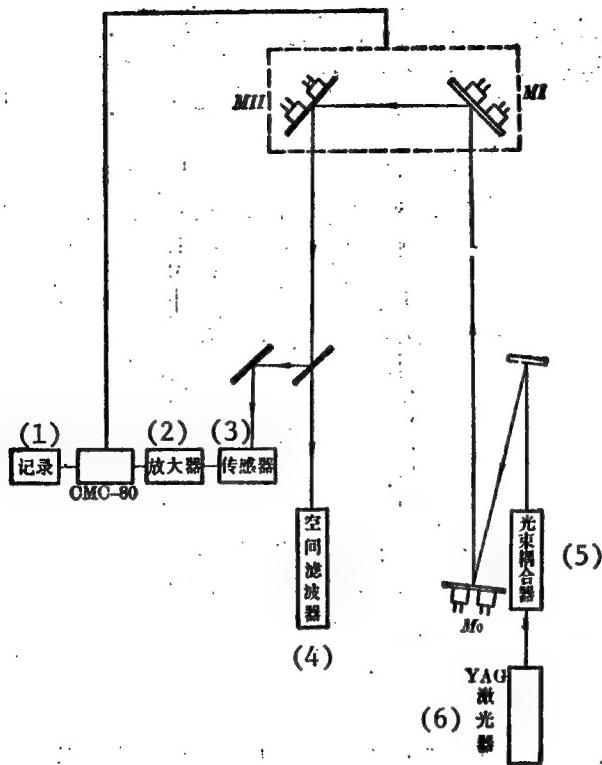


Fig. 7 Experimental layout of the CMC-80 based laser auto-alignment system

Key:

1. Recorder
2. Amplifier
3. Transducer
4. Spatial filter
5. Beam coupler
6. Laser

Experiments were performed for the following four beam deviation situations:
 (1) Beam deviation is simulated by advancing the azimuth and pitch motors of M_o 30 steps each; (2) azimuth and pitch motors of M_o move backward 30 steps each; (3) azimuth motor of M_o advanced 30 steps and pitch motor of M_o reversed 30 steps; (4) azimuth motor of M_o reversed 30 steps and pitch motor of M_o advanced 30 steps. Table 1 shows the values of the data converted into the decimal system.

Based on these experimental data, we computed the average accuracy of the auto-alignment system controlled by a CMC-80 computer. The accuracy of orientation is 1.8 percent and the accuracy in aiming is 1.4 percent. The corresponding angular drift is 0.5" and the axial drift is 102 μm of the main beam entering the spatial filter. In the experiment the temporal fluctuation of the laser power was eliminated with computer software.

Table 1. Data in decimal system

Deviation of laser beam		Aligned (original)				Deviated				Auto-aligned				
		Quadrant	1	2	3	4	1	2	3	4	1	2	3	4
Azimuth	↓ 30	orientation	53	52	51	54	30	46	35	19	44	44	46	42
Pitch	↓ 30	aim	56	57	59	62	72	55	41	52	59	58	60	59
Azimuth	↓ 30	orientation	31	30	32	31	22	22	35	32	35	36	32	35
Pitch	↓ 30	aim	43	41	42	41	32	33	48	64	39	39	40	40
Azimuth	↓ 30	orientation	35	37	39	36	17	24	39	24	31	31	30	31
Pitch	↓ 30	aim	45	48	46	43	35	30	43	51	45	45	46	46
Azimuth	↓ 30	orientation	25	27	24	31	25	26	20	19	26	37	26	26
Pitch	↓ 30	aim	43	44	41	45	51	47	34	35	44	42	41	43

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CSO: 8111/0461

APPLIED SCIENCES

TIME-RESOLVED X-RAY SPECTRA STUDIED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12 No 9, Sep 85 pp 570-572

[Article by Pan Chengming [3382 2052 2494], Yin Guangyu [3009 0342 5940], Zhao Shicheng [6392 0013 6134], and Zhu Daqing [2612 1129 1987]: "Calibration of X-Ray Streak Camera"]

[Text] Abstract: The interaction of laser light with plasma is described which offers X-rays directly or indirectly. The specifications as well as the calibration of the X-ray streak camera are presented. Its physical application in laser produced plasma is indicated.

X-ray emitted by the laser plasma plays a direct or indirect role in the interaction of laser and plasma. The characteristic length is several micrometers to several hundred micrometers and the characteristic time is several picoseconds to several hundred picoseconds. A device for diagnosing the time resolved X-ray must therefore have a time resolution of several picoseconds to several hundred picoseconds. An -ray streak camera is designed for this specific purpose.

Before an X-ray streak camera is put in use, it must be calibrated for time resolution, dynamic range, scanning linearity, and trigger jittering. Its intensity and linear output range must be quantified together with its spectral resolution devices such as reflecting mirrors and filters.

1. Calibration of Time Resolution

The time resolution of an X-ray streak camera is defined as full width at half maximum (FWHM) of the received signal of the X input. Physically the measurement is done by using a short X-ray pulse on the cathode of the streak camera and the FWHM value is then read off the temporal change of the pulse intensity shown on a temporal analyzer.

If the resolution time of the streak camera is T_{xc} and the pulse width of the incident X-ray is T_{xi} , then the pulse width of the camera output is given by

$$T_0 = (T_{xi}^2 + T_{xc}^2)^{1/2} \quad (6)$$

Here we assume that the pulse has a Gaussian distribution. Therefore, knowing T_{xi} , one may obtain T_{xc} by measuring T_o . A high power laser hitting a metallic target (e.g. Fe, Cu, Al) serves as a source for short X-ray pulse. The apparatus is shown schematically in Figure 1.

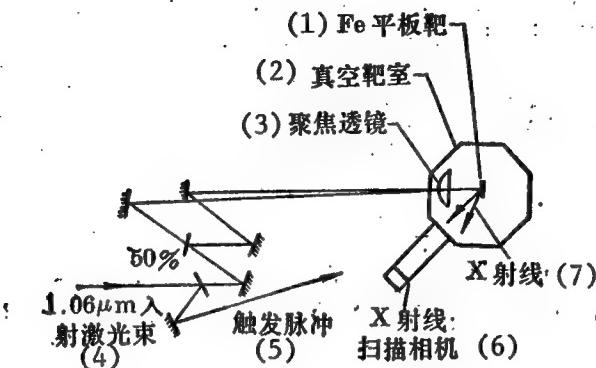


Fig. 1 Calibration Apparatus for the Time Resolution of X-ray Streak Camera

Key:

1. Planar Fe target
2. Vacuum target chamber
3. Focusing lens
4. $1.06 \mu\text{m}$ incident laser beam
5. Trigger pulse
6. X-ray streak camera
7. X-ray

2. Calibration of Dynamic Range

In 1976 W. Friedman first proposed the concept of the time resolution and intensity correlation of an X-ray streak camera. The basic idea is that the output pulse width may be increased by increasing the intensity of the incident light pulse of a constant pulse width. The dynamic range is defined as the change of the incident light pulse intensity when the output pulse width is increased by 20 percent when the incident pulse width (FWHM) is held constant, see Figure 2. When a film is used as the element for recording the output light pulse, the lower bound of the dynamic range is the fog of the film. When an optical multichannel analyzer (OMA) is used, the lower bound of the dynamic range is the noise level of the OMA. If the streak camera has sufficient gain, a single photoelectron will produce a signal much greater than the noise. In this case, the definition above is meaningless. For a practical dynamic range, the lower bound may be considered as the minimum level measurable by the streak camera.

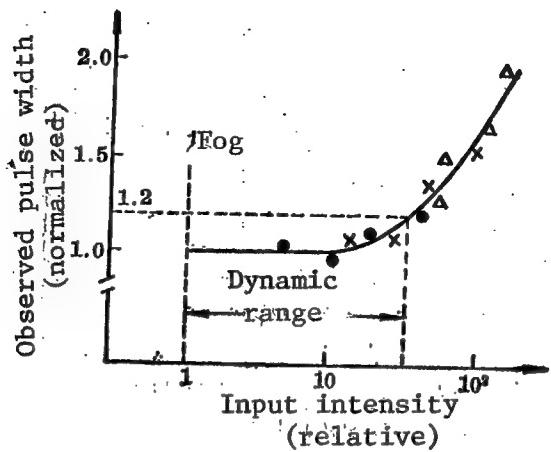


Fig. 2 Dynamic Range of an X-ray Streak Camera

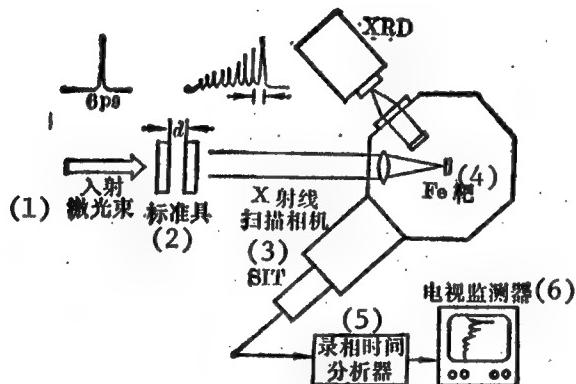


Fig. 3 Calibration Setup for the Dynamic Range of an X-ray Streak Camera

Key:

1. Incident laser beam
2. Etalon
3. X-ray streak camera
4. Fe target
5. Recording time analyzer
6. Television monitor

The calibration setup for the dynamic range of the streak camera is shown in Figure 3. A single picosecond pulse enters an etalon made of two reflecting mirrors and produces a pulse sequence with a constant time interval and decay rate.

If the separation of the two mirrors in the etalon is d , then the separation between two adjacent pulses is

$$\Delta t = 2d/c \quad (2)$$

When the pulse sequence is used in the irradiation of metallic targets such as Cu, Al, and Fe with an X-ray conversion efficiency of ξ , the X-ray intensity produced by the m th pulse is $I_{mx} = I_1(R_1R_2)^{m-1}\xi$, and the X-ray intensity converted from a light pulse of intensity I_1 is $I_{1x} = T_1T_2I_0\xi$. Here R_1 , R_2 , T_1 and T_2 are respectively the reflectivity and transmissivity of the two mirrors of the etalon. If the conversion efficiency is different from different intensity, we assume the conversion efficiencies to be ξ_1 , ξ_2 , ..., ξ_m for the m pulses. Then the X-ray intensity generated by the m th laser pulse is $I_{mx} = I_1(R_1R_2)^{m-1}\xi_m$, and the X-ray intensity produced by the laser pulse of intensity I_1 is

$$I_{1x} = T_1 \cdot T_2 \cdot I_0 \cdot \xi_1$$

In the calibration the X-ray intensity is measured with an XRD detector.

The dynamic range is limited mainly by the space charge effect in the phaser tube.

3. Intensity Calibration

The intensity calibration apparatus of the X-ray streak camera is shown in Figure 4. The XRD detector and the streak camera (including the reflection mirror, the filter and the spectral resolution system) are at an angle of 45° with respect to the laser axis.

The X-ray intensity I_a on the receiving system (film or CCD recorder) is

$$I_a = \frac{I_i d C_q T C_f \xi}{m_x m_t U_c} \quad (3)$$

where I_i is the incident X-ray flux, d is the slit width, C_q is the conversion efficiency of the photocathode, T is the electron transmissivity of the phaser tube, C_f is the electro-optic fluorescence efficiency, m_x is the spatial magnification of the image, m_t is the temporal magnification of the image, U_c is the image output speed change, and ξ is the efficiency of the detector (film or CCD detector). In Eq.(3), only C_q depends on the X-ray energy and all the other parameters depend only on the construction of the streak camera and physical constants. Equation (3) can therefore be written as

$$I_a = A C_q I_i \quad (4)$$

where A is a constant depending on all other components of the camera except the photocathode. The calibration procedure determines the value of A, that is,

$$A = \frac{I_a}{C_q I_i} \quad (5)$$

C_q is determined independently using the method of Ref. 1. I_i is the incident X-ray flux and is measured with an XRD.

The calibration procedure for the linear output range of the X-ray streak camera is similar to above. By varying the laser intensity and hence the incident X-ray flux I_i , the linear range where A varies with I_i linearly is found.

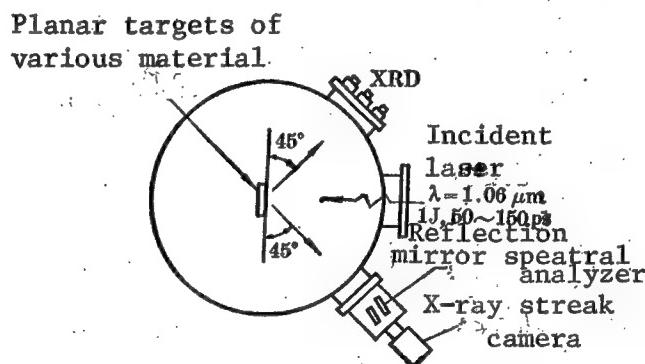


Fig. 4. Intensity Calibration Apparatus of the X-ray Streak Camera

4. Nonlinearity, Trigger Delay and Jitter

Nonlinearity of the scanning velocity not only shows up in the time axis but also affects the intensity. This is because any compression of the time axis due to nonlinearity will increase the intensity even if the pulse intensity fed into the system is held constant. To calibrate the linearity, the setup of Figure 3 may be used. The etalon is used to generate a sequence of laser pulses equally separated in time to bombard a target. The separation between the X-ray pulses produced by the laser plasma is identical to the separation of the laser pulses. The distance between the X-ray pulses is $\Delta X = m \pm \Delta m$ and the corresponding time interval is Δt . The scanning velocity v is therefore $\Delta X / \Delta t$ and the nonlinearity of the scan is $\Delta m/m$.

In order for the streak camera to form an image at the center of the screen, the trigger signal must arrive before the X-ray signal reaches the slit on the camera. This can be accomplished by suitably delaying the time using fiber optics or cable.

In single measurements using the streak camera, trigger jitter does not affect the measured value. For small signal X-ray pulses, multiple exposure and averaging are required. Time jitter of the trigger causes jumps of the image on the screen and measurement errors. If the FWHM value of the trigger jitter T_t obeys a Gaussian distribution, then

$$T_j = (T_i^2 + T_s^2 + T_r^2)^{1/2} \quad (6)$$

where T_x is the width of the incident X-ray pulse, T_r is the time resolution of the camera, and T is the FWHM value of the integrated incident X-ray signal.

The trigger jitter is therefore

$$T_j = (T^2 - T_s^2 - T_r^2)^{1/2} \quad (7)$$

If the jitter is less than the time resolution, it may be ignored. Trigger jitters may be compensated using computer software.

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CSO: 8111/0461

32W OUTPUT FROM Cu-VAPOR LASER OBTAINED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12 No 9,
Sep 85 p 550

[Text] Cu vapor laser is a self-terminating transition, high gain gas discharge laser. It is capable of high power and high efficiency operation. It emits a visible green line (510.6 nm) and a visible yellow line (578.2 nm). The Shanghai Institute of Optics and Fine Mechanics began its research of Cu-vapor laser in 1983 and has achieved 10W, 15W and 23W operation at 6-10 kHz using a ϕ 23x1000 mm discharge element. The operation time exceeded 200 hours. Using a ϕ 35x1000 mm discharge element and a 6 kHz repetition rate, an average output power of 26.5W was obtained last year. Recently, after improving the excitation source and other working parameters, the unit delivered 32W of output power. The laser beam diameter was 35 mm, the divergence angle was 5 mrad, the pulse width was 30 ns, the buffer gas used was neon and the lasing efficiency was 0.45 percent. [Shanghai Institute of Optics and Fine Mechanics]

9698/8309
CSO: 8111/0461

APPLIED SCIENCES

BRIEFS

COMPACT, SELF-HEATED CuCl₂ LASER--The Nanjing Engineering College has successfully developed a compact, sealed, self-heated CuCl₂ laser. The discharge length of the laser is 38.5 cm, the inner diameter is 0.9 cm, the output power is about 800 mW, the power stability is 2 percent, and the service life is 300 hours. The laser has unique structural design and was produced with a special technique. The discharge tube is of the concave trough type and a magnetic field is applied at the window to reduce the window contamination by the copper vapor. The working material was also specially processed. This achievement of the Nanjing Engineering College was certified in a meeting held by the Jiangsu Provincial Scientific Committee and the laser is being mass produced by the Shanghai Yaming Lightbulb Plant. [Text] [Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12, No 12, 20 Dec 85 p 751] 9698/6091

COMPACT TEA CO₂ LASER--The Nanjing Engineering College has developed a compact TEA CO₂ laser. The external dimensions are 76 mm diameter by 240 mm, comparable to that of a regular He-Ne laser. The case is machined from a lithium mica microcrystalline glass. The energy per pulse is 100 mJ. The average output energy remains above 60 mJ after 10⁶ pulses at a repetition rate of 1 Hz. The pulse width is 40-50 ns, the peak power is greater than 1 MW, and the output stability is 2 percent. Researchers at the Nanjing Engineering College developed this laser with several new technologies. First, they developed a compact, sealed preionization electrode and obtained a strong and uniform glow discharge in a very small volume. Second, they introduced some CO and H₂ gas into the working medium and obtained the optimum mixture ratio. Third, they placed a diaphragm in the resonance cavity to prevent contamination of the reflection mirror. This research result obtained by the Nanjing Engineering College has passed the certification in a meeting held by the Jiangsu Provincial Scientific Committee on 26 June. The Nanjing Electron Tube Plant will produce and market the compact TEA CO₂ laser. [Text] [Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12, No 12, 20 Dec 85 p 751] 9698/6091

CSO: 4008/34

Explosives Technology

STUDIES OF TRINITROMETHYLATION REACTIONS (II) THE SYNTHESIS OF NONANITRO-MESITYLENE AND RELATED COMPOUNDS

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 4, Nov 85 pp 1-8

[English abstract of article by Zhou Faqi [0719 4099 1477] and Fan Nengting [2868 5174 1694]]

[Text] Utilizing the trinitromethylation reaction, nonanitromesitylene is synthesized from s-benzene-tricarboxaldehydoxime via hexanitromesitylene and its trispotassium salts, using nitrogen tetroxide as the nitration reagent. The products related to the synthesis of nonanitromesitylene are described in this paper, namely 3,5-bis(trinitromethyl)benzaldehyde, 5-trinitromethyl-1,3-phthalaldehyde, 3,5-bis(dinitromethyl)benzaldehyde and its bispotassium salt, 5-dinitromethyl 1,3-phthalaldehyde and its potassium salt, m-trinitro-methyl benzaldehyde, m-dinitromethyl benzaldehyde and its potassium salt.

Explosives Technology

STUDIES OF THE CATALYTIC ACTION OF LEAD SALICYLATE ON THE THERMAL DECOMPOSITION OF HMX USING TIME-OF-FLIGHT MASS SPECTROMETER

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 4, Nov 85 pp 9-16

[English abstract of article by Jing Zhongxing [2529 0022 5281] and Bai Mulan [4101 2606 5695]]

[Text] Time-of-flight mass spectrometer has been used to study the effects of lead salicylate as a catalyst for the thermal decomposition of HMX at a temperature range of 150°C to 300°C. Its effects on the dissociated gaseous products and decomposition rate of HMX are determined and the kinetic parameters of thermal decomposition calculated. The catalytic activity of lead salicylate is studied and the mechanism of the catalytic action of lead salicylate is discussed in the paper.

Explosives Technology

NUMERICAL METHODS FOR SIMULATING SHAPE FORMATION IN SELF-FORGING-FRAGMENTS

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 4, Nov 85 pp 25-32

[English abstract of article by He Gaoyu [0149 7559 3768], He Shunlu [0149 7311 6922] and Li Luyin [2621 6922 5593]]

[Text] In this paper two-dimensional numerical methods for simulating shape formation of self-forging-fragments are studied. The dynamic equations are based on a perfectly-elastic, ideally plastic-fluid model. The emphasis is placed on the processing techniques of different calculating methods, such as artificial viscosity, calculation of the sliding surface and regionalization (re-netting). A numerical example for the shape formation process of the self-forging-fragment is given and compared with experimental X-ray photos, showing good agreement between them.

Laser Technology

OPTIMIZATION OF INFORMATION PROCESSING METHODS IN LASER RANGEFINDING

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 4, Nov 85 pp 33-38

[English abstract of article by Tao Huacheng [7118 0553 2052] and Lu Ming [7120 2494]]

[Text] In laser rangefinding for an A/A artillery system, the two salient problems to be confronted presumably are: (1) how can the range be predicted if the radiated laser beam has no return waves? and (2) at the initial phase, how many times in succession should the return wave be received before the director can start working? In this paper, several methods are proposed as reasonable solutions. Quantitative calculations and analysis of these methods through computer simulation are given and the results are listed in the appendix.

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CSO: 4009/40

Motion Detection

CORRELATIVE MOTION DETECTION BY VISUAL SYSTEM

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 4, Nov 85 pp 17-24

[English abstract of article by Zhang Shaowu [1728 1421 0710], Wang Xiang [3769 5046] and Sun Qijian [1327 0366 1017]]

[Text] Motion detection plays an important role in visual systems. Based on Reichardt's model of motion detection for insects, an engineering model of motion detectors with multiple-channels is proposed in this article. This model is capable of detecting direction and transverse angular velocity in a wide available range in real time. Not only can it detect the motion of a pattern with a discriminatable outline and edge, but it can also detect the motion of a texture pattern without a discriminatable outline and edge.

The parameters of the model are suggested as follows:

1. The time constant τ_L of the low-pass filter of the first order influences the available range of velocity detection. It depends on the space d between two receivers of the motion detector--delay time t_a corresponding to the superior limit of detectable velocity and delay time t_b corresponding to the inferior limit of detectable velocity as well as the degree of precision required in velocity detection.
2. The ratio of the time constant high-pass filter τ_H to the loss-pass filter τ_L also influences the available range of velocity detection. The smaller the time constant τ_H is, the greater the superior limit of detectable velocity will be.
3. The correlator sampling time T is determined as follows:

$$T \geq \frac{1}{2\epsilon} \times [\tau_L + 2t_a + 2]$$

4. The available range of velocity detection by motion detectors having multiple-channels consisting of N channels is enlarged to $\frac{d_0}{t_b} \times \left(\frac{t_a}{t_b}\right)^N$. The space d between the two receivers of the motion detector in the k th channel can be determined as follows:

$$d_k = d_0 \times \left(\frac{t_a}{t_b}\right)^k, k = 0, 1, \dots, N.$$

Nuclear Science

INVESTIGATION OF FLOW-INDUCED VIBRATION FOR HEAT EXCHANGER SIMULATOR IN NUCLEAR REACTOR

Beijing HE KEXUE YU GONGCHENG [CHINESE JOURNAL OF NUCLEAR SCIENCE AND ENGINEERING] in Chinese Vol 5 No 4, Dec 85 pp 294-305

[English abstract of article by Hang Zilong [5592 5261 7893], Zhao Soujun [6392 1344 6874] and Li Haibao [2621 3189 1405], et al., of Southwest Institute of Nuclear Reactor Engineering]

[Text] The experimental and analytical results of flow-induced vibrations for a simulator heatexchanger in a nuclear reactor are presented. The tests were carried out in a water loop used for studying flow-induced vibrations for the reactor structure and components. The simulator is about 4 meters long and has a rectangular cross-section with 35 heatexchange tubes.

Both the amplitudes and strains of the tubes in axial flow and cross flow regions are measured. The maximum values of amplitude and strain of the tubes as a function of the velocity and length of the tube-span are given. The results of the measurements are compared with the calculated values.

Nuclear Science

THERMAL SHOCK STRESS MEASUREMENTS OF FAST NEUTRON PULSE REACTOR

Beijing HE KEXUE YU GONGCHENG [CHINESE JOURNAL OF NUCLEAR SCIENCE AND ENGINEERING] in Chinese Vol 5 No 4, Dec 85 pp 306-314, 355

[English abstract of article by Jin Zhanglin [6855 7022 2651] of Southwest Institute of Nuclear Physics and Chemistry]

[Text] In this paper a method for the measurement of surface stress distribution of a fast neutron pulse reactor during a blasting pulse is presented. The weakest points with maximum stress concentration factors were found and monitored in operation. A stress vs lower fission yield curve was made, then extrapolated to the next higher yield point until the maximum allowable stress was reached. In this way the maximum pulse yield was safely obtained.

Nuclear Science

REACTOR CORE THERMAL-HYDRAULIC DESIGN OF QINSHAN NUCLEAR POWER PLANT

Beijing HE KEXUE YU GONGCHENG [CHINESE JOURNAL OF NUCLEAR SCIENCE AND ENGINEERING] in Chinese Vol 5 No 4, Dec 85 pp 315-323

[English abstract of article by Chen Yuxiang [7115 3022 3276] and Zhou Quanfu [0719 0356 4395] of Research and Design Institute No 728]

[Text] The PWR core thermal-hydraulic design, including the design objective, criteria and main design parameters, for the Qinshan Nuclear Power Plant is described. In addition, thermal-hydraulic tests related to the design are also discussed briefly.

Emphasis is placed on the modified single-channel model design method. Some important analytical results using the PWR core fuel rod thermal characteristics analysis program are also given.

Nuclear Science

STUDY OF THE SOLIDIFICATION OF SPENT TRIBUTYLPHOSPHATE SOLVENTS

Beijing HE KEXUE YU GONGCHENG [CHINESE JOURNAL OF NUCLEAR SCIENCE AND ENGINEERING] in Chinese Vol 5 No 4, Dec 85 pp 332-337

[English abstract of article by Luo Shanggeng [5012 0006 1649] of the Institute of Atomic Energy, Beijing; and S. Drobnik of KFK, West Germany

[Text] The processing conditions for solidification of spent TBP-solvents and its product characteristics are described in this paper. The resistance to leach and radiation and the thermostability and durability of storage of products made from simulated and real TBP-solvents are measured. The loadage of the solidification product is as high as 70 wt percent. The analysis indicates that the solidification products meet the requirements for storage and final disposal.

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CSO: 4009/38

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